CHARACTERISTICS OF SMALLMOUTH BASS AND OZARK BASS POPULATIONS IN BUFFALO NATIONAL RIVER, ARKANSAS

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Scope and Method of Study: This study involved an investigation of smallmouth bass and Ozark bass populations in Buffalo River, Arkansas. Fish were collected primarily by electofishing 12 sites seasonally between June 1980 and September 1981. The objectives were to 1) determine whether habitat was limiting populations, and 2) whether levels of canoeing activity were having detrimental effects on the fishery. Population estimates, standing crop, condition factors, growth rates, mortality and food habits were analyzed. Difference that existed were correlated with habitat availability and levels of recreational canoe use.

Findings and Conclusions: Density and standing crop for Buffalo River smallmouth bass and Ozark bass populations were comparable to those in rivers and streams in Missouri and Oklahoma but were lower than those in Iowa and Wisconsin, where waters were more productive.

The smallmouth bass/Ozark bass populations in the Buffalo River appear to be regulated by a space-food mechanism during periods of low flow. During extreme low flows associated with drought, habitat primarily substrate and depth and its effects on food availability appeared to become a limiting factor for both species.

Partitioning of habitat and food items to lessen competition appeared to occur. Partitioning occurred along the velocity and substrate axes in summer. There was also a decline in food overlap as both species increased in length. Intraspecific competition was reduced by diet shifts from insects to fish and crayfish; interspecific competition was minimized because adult Ozark bass fed primarily on crayfish and insects whereas smallmouth bass utilized fish.

Existing levels of canoe activity did not appear to be seriously impacting the fishery. Increased canoe levels were found to be correlated with increased spring standing crops and higher condition factors in summer 1981 for smallmouth bass and with decreased condition factors for summer Ozark bass populations. The fishery did not appear to be overharvested.

ADVISER'S APPROVAL ______________________________

CHARACTERISTICS OF SMALLMOUTH BASS AND OZARK BASS

POPULATIONS IN BUFFALO NATIONAL

RIVER, ARKANSAS

Thesis Approved:

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Dean of the Graduate College

PREFACE

This study is concerned with the population characteristics of the two principal game fish species, smallmouth bass, *Micropterus dolomieui*, and Ozark bass, *Ambloplites constellatus*, inhabiting Buffalo National River. The primary objectives were to determine what effect habitat availability and/or various levels of recreational boating activity were having on these two species.

I want to express my appreciation to my major advisor, Dr. O. Eugene Maughan, for his guidance, encouragement and assistance throughout this study. I also express appreciation to Dr. Anthony Echelle and Dr. Larry Talent for agreeing to serve on my committee on short notice and their assistance in preparation of this thesis.

Special thanks is given to Dr. Milford R. Fletcher, Chief, Division of Natural Resource Management, Southwest Region of the National Park Service, who established the program and provided the funding without which this study would not have been possible. Thanks are also given to Buffalo National River Superintendent Alec Gould and Chief Ranger Carl Hinrichs and their predecessors, Superintendent John Turney and Chief Ranger John Welch, who not only allowed me to take time from my regular duties to attend Oklahoma State University to accomplish this research but who also allowed other members of their staff to assist with data collection and analysis.

I thank Steve Chaney for not only serving as one of the regulars on the sampling crew, but for "holding down the fort" while I was immersed in research and away from my regular duties in the park. A note of thanks is also given to all the "boat people", members of the park staff and volunteers, who served on the electroshocking boat, pulled seines, ran tansects, conducted creel censuses, or served in the lab, especially John Cooper, Norm Geltz, Jeff Hager, Mike Monda, Todd Patrick, Charles Rogers, Jimmy Wheat and Mike Widner.

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CHAPTER I

INTRODUCTION

Buffalo National River was established in 1972 with Congressional passage of Public Law 92-237. This law designated the lower 221 km of the Buffalo River and 38,757 ha of land along its banks as a unit of the National Park Service.

Recreational use of the river has increased dramatically since the creation of Buffalo National River. Canoeing, which is the primary recreational use of the river, has increased from approximately 5,500 canoes in 1963 to 46,000 in 1979 and 51,000 in 1981 (U.S. National Park Service 1982). Fishing, johnboating and swimming have also increased. Increased recreational use has caused concern among local fishermen as well as among state and federal biologists and land managers. The concern centers around the question of whether high levels of recreational activity, during the spawning seasons of the smallmouth bass (*Micropterus dolomieui*) and the Ozark bass (*Ambloplites constellatus*), the two principal game fish of the river, has detrimentally affected the fishery. There has also been concerns about the effects of proposed increased stocking rates of channel catfish (*Ictalurus natalis*). Park management has taken the position that the status of the fishery should be evaluated prior to initiating a stocking program. The principle question to be answered is whether an additional predator would impact the present game fish species. The need for information on the status of the major game fish species of Buffalo National River to allow park management to address these concerns was the basis for initiating this study.

Little research has been conducted on the Buffalo River fishery. The available information deals principally with species distributions (Black 1940; Baker 1953; Baker and Brown 1957; Arkansas Game and Fish Commission 1962; Cashner and Brown 1977). There has, however, been some research on the principle game fish, the smallmouth bass. Peek (1965) examined growth rates in the 1962 and 1964 populations of smallmouth bass at six locations within what is now Buffalo National River. Although the absolute growth rates were computed erroneously (Carlander 1977), overall growth rates were shown to increase in a downstream direction. However, older smallmouth bass grew equally well in upstream sites and downstream sites. Peek attributed the between-sites growth difference to temperature. Kilambi, Robison and Adams (1977) sampled three sites on the Buffalo River during 1975-1976 and established baseline growth rates for the smallmouth bass populations. The annual mortality rate was 36%, May and June was the period of annulus formation, and fish and crayfish wwre the major food items. Excepting the two studies just described there have been no other detailed studies on smallmouth bass in Arkansas streams. There has been even less work on Ozark bass. Cashner and Suttkus (1977) identified the Buffalo River rock bass as a new species, which they described as the Ozark bass, *Ambloplites constellatus*. The Ozark bass is found only in the Ozark Upland Province of Arkansas and Missouri but no detailed studies have been done on any *Ambloplites* species in Arkansas streams.

This study was designed to examine the population characteristics of smallmouth bass and Ozark bass at twelve sites along the Buffalo River. The purposes were (1) to determine if differences exist among fish between sites and seasons of the year, and (2) to determine whether such differences are associated with habitat characteristics, including recreational use. The objective was to determine whether habitat is limiting populations and whether high levels of canoe activity are detrimental to the fishery.

CHAPTER II

DESCRIPTION OF STUDY AREA

The Buffalo River (Figure 1), a tributary of the White River, is located in the Ozark Mountains of north central Arkansas. The basin is approximately 112.7 km long, averages 35.4 km in width and drains an area of 3,465 km^2. The Buffalo River originates in the Boston Mountains of Newton County and flows for 238 km in an easterly direction through Searcy and Marion Counties. The eastern half of the basin dissects the Springfield Plateau and near the mouth it cuts through the Salem Plateau (U.S. Army Corps of Engineers 1964). The Buffalo River enters the White River approximately 50 km downstream of Bull Shoals Dam and 18 km upstream of the mouth of the North Fork River.

The topography is rough to mountainous, the only level land being linear tracts along ridge tops and discontinuous floodplain crescents scattered throughout the alluvial stream valleys (U.S. National Park Service 1975). Basin relief ranges from 783 m at the headwaters to 116 m at the mouth; stream gradients range from 2.9-7.6 m/km in the headwaters to less than 0.5 m/km in the lower 122 km of the river (U.S. Army Corps of Engineers 1964).

The river has 64 tributaries, all of which are primarily short with perennial and intermittant flows. The three largest tributaries are the Little Buffalo River, Big Creek and Richland Creek with drainage areas of 368, 357 and 331 km^2, respectively (Babcock 1976).

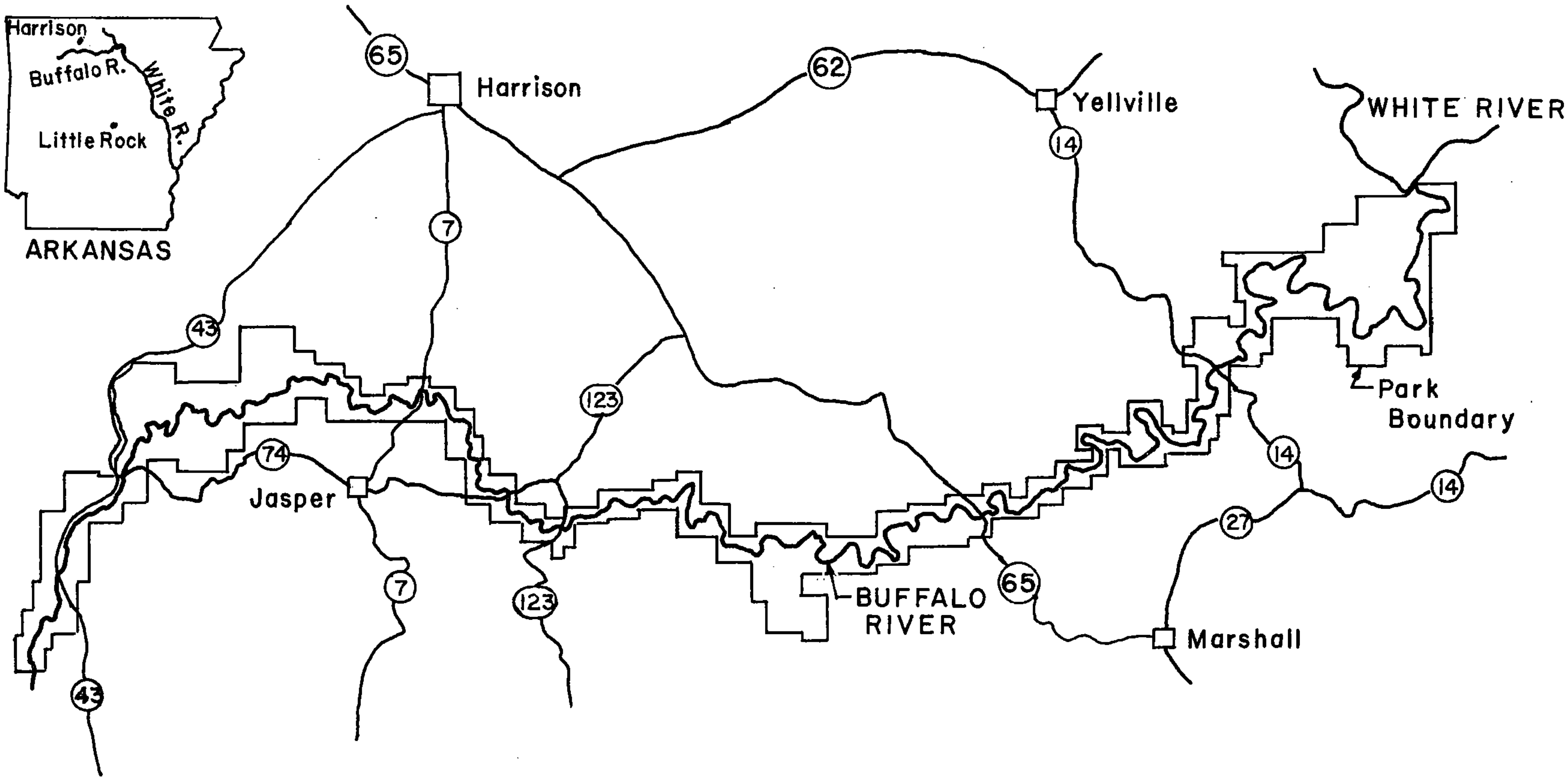

Figure 1. Buffalo National River, Arkansas.

Geologic formations in the basin are sedimentary in origin with shale and sandstone capping the Boston Mountain portion of the watershed and dolomite and limestone dominating the eastern portion of the basin. The basin is rural and sparcely populated with about 13,000 people. Approximately 79% of the watershed is forested and 20% is in agricultural production. Oak-hickory is the predominant forest community in the basin but oak-pine and cedar glades are also common. Soils in the floodplain are sandy and silty loams but the easily eroded slopes are covered with thin layers of cherty loam and clays.

The climate of the region is characteized by hot summers and mild winters. The average annual temperature is 14.4°C. Temperatures in July average 26.7°C often reaching 37.8°C during mid-day. January temperatures average 4.4°C occasionally falling to -17.7°C or lower at night. Annual rainfall averages 123.4 cm and is distributed relatively uniformly throughout the year (U.S. National Park Service 1975). Annual runoff averages 40.8 cm (Babcock 1976).

The U.S. Geological Survey stream gage located at Highway 65 bridge, 95.8 km above the river's confluence, has recorded an average discharge of 28.8 m^3/s between 1939 and 1981. Maximum discharge during the 42-year period was 3,140 m^3/s which occurred in November 1973. In 1980, during a severe drought, discharge ranged from a maximum of 217 m^3/s to a minimum of 0.31 m^3/s with a mean discharge of 13.4 m^3/s (Appendix A). In 1981, flow increased slightly; mean flow was 15.1 m^3/s but it was still below the 1979 pre-drought flows. In 1979 discharge ranged from a maximum of 912 m^3/s to a minimum of 0.79 m^3/s with a mean discharge of 41.1 m^3/s (U.S. Geological Survey 1979, 1980, 1981).

Water quality of the Buffalo River during normal flow is exceptionally high and deviation from the high quality is attributable to surface runoff and not to point sources of pollution or recreational usage (Meyer and Woomer 1978). Dissolved oxygen remains near or above saturation year round. Average daily temperatures vary from 5.3°C in December to 30.9°C during July, with temperatures generally increasing in a downstream direction. Turbidity is generally low and pH ranges from 6.6 to 8.8. Conductivity and alkalinity increases in the downstream direction with conductivity levels ranging from 28 micromhos/cm in the upper reaches of the river in December to 234 micromhos/cm in the middle reaches in June.

Fifty nine species of fish representing 12 families have been recorded for the river (Cashner and Brown 1977). The most common pool species are the longear sunfish (Lepomis megalotis), bigeye shiner (Notropis boops) and the duskystripe shiner (N. pilsbryi). The most common riffle species are the yoke darter (Etheostoma juliae), rainbow darter (E. caeruleum), duskystripe shiner and the largescale stoneroller (Campostoma anomalum) (Becker and Kilambi 1975). The principle game fish is the smallmouth bass.

Twelve study sites (Figure 2) were selected, eleven on the Buffalo River itself and the twelfth on Calf Creek, a tributary that enters the river at river kilometer 99.8. Criteria used in selection of sampling locations were 1) accessibility [an electroshocking boat was used and low water levels during summer and fall restricted access to some areas] and 2) the level of canoe use. Each site consisted of a pool and the adjacent upstream riffle. The location of the 12 sites were:

Site 1: 0.8 km above the mouth of Clark Creek, T16N, R23W, Section 36 at river kilometer 206.

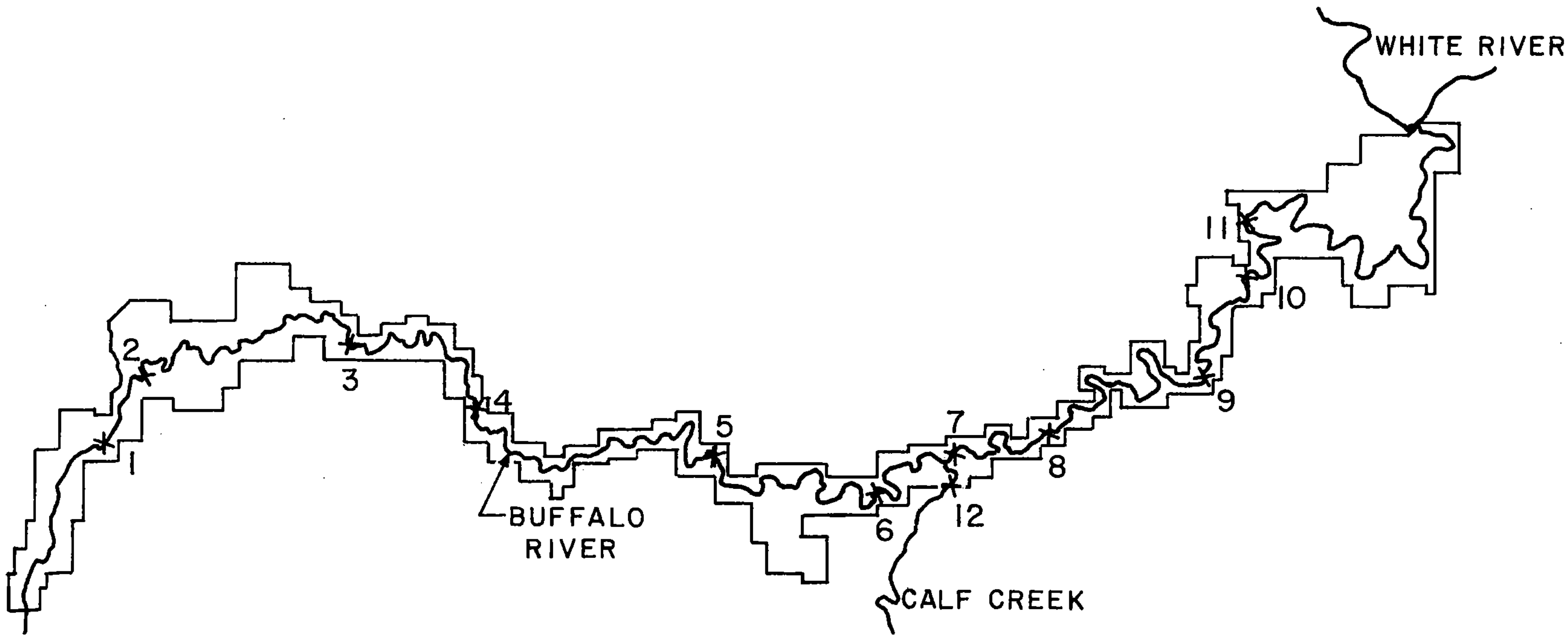

Figure 2. Sample site location map.

Site 2: 0.6 km below the mouth of Steel Creek, T16N, R22W, Section 17 at river kilometer 198.

Site 3: 5.8 km above the Highway 7 bridge, T16N, R21W, Section 11, at river kilometer 171.

Site 4: 1.9 km above the Hasty low water bridge, T16N, R20W, Section 27 at river kilometer 155.

Site 5: Mouth of Cane Branch, T16N, R18W, Section 31 at river kilometer 131.

Site 6: White Bluff, T15N, R18W, Section 31 at river kilometer 109.

Site 7: Tyler Bend, above Mill creek, T16N, R17W, Section 34 at river kilometer 98.

Site 8: Mouth of Bear Creek, T16N, R16W, Section 29 at river kilometer 87.

Site 9: 0.8 km below the mouth of Spring Creek, T16N, R15W, Section 16 at river kilometer 61.

Site 10: Mouth of Panther Creek, T17N, R15W, Section 27 at river kilometer 49.

Site 11: 1.1 km above the mouth of Rush Creek, T17N, R15W, Section 15 at river kilometer 40.

Site 12: Calf Creek, 1.6 km above its confluence with the Buffalo River, T15N, R17W, Section 3.

Physical characteristics of each site are summarized in Table 1, habitat parameters at each site are provided in Appendix B, and levels and periods of canoe use are given in Table 2.

Table 1. Physical characteristics of the 12 study sites on the Buffalo River, Arkansas.

Site #	Area (ha)	Length (m)	Average width (m)	Mean depth (m)	Maximum depth (m)	Principal substrate	Aquatic vegetation (m^2-% of site)	Gradient (m/km)
1	0.54	223	24.2	0.8	3.0	Gravel/cobble	144-2.7	3.2
2	0.29	200	13.8	0.5	3.7	Gravel	0-0.0	2.1
3	0.95	286	22.5	0.9	2.4	Gravel	18-0.2	1.5
4	0.93	400	23.7	0.8	2.1	Gravel	24-0.3	1.4
5	0.71	240	30.1	0.6	1.8	Gravel	146-2.0	1.0
6	1.63	597	28.1	0.7	2.2	Gravel	2,460-15.1	1.4
7	1.81	600	29.4	1.3	3.5	Silt	0-0.0	1.1
8	1.92	550	35.2	0.8	2.2	Gravel	1,660-8.7	0.6
9	3.68	1,121	32.7	0.6	1.5	Gravel	2,744-7.5	0.5
10	3.82	1,100	34.1	0.6	1.5	Gravel-bedrock	1,930-5.0	0.5
11	7.32	1,600	45.7	0.8	2.5	Gravel	6,385-8.7	0.8
12	0.13	100	12.9	0.5	1.6	Gravel	35-2.7	2.5

Table 2. Total number of canoes and months of peak canoe use at each site on the Buffalo River, Arkansas in 1981.

Site number	Number of canoes	Months of peak use
1	229	April-May
2	7,730	April-June
3	5,181	April-June
4	3,586	April-August
5	1,263	April-June
6	5,077	April-August
7	5,077	April-August
8	2,338	April-September
9	12,194	April-September
10	9,571	April-October
11	9,571	April-October
12	0	-

Source: United States National Park Service, Draft Proposal/Environmental Assessment, River Use Management Plan, Buffalo National River (1982).

CHAPTER III

MATERIALS AND METHODS

Excepting sites 9, 10, and 12 which were not sampled in fall 1980, the 12 study sites were sampled once in the fall, and once in the winter of 1980 and once in the spring of 1981. Except for sites 5, 7, and 9 during the summer of 1980 that were sampled only twice, each site was sampled three times during each of the summers of 1980 and 1981 (Appendix C).

Fish were sampled with a boat-mounted, Coeffelt VVP 15 electroshocking unit operated on DC pulse at 600 volts, 3-6 amps, a pulse frequency of 80-100 cycles/second and a 40 to 50% pulse width.

A unit of effort consisted of electroshocking the entire site. Three units were generally made on each sample day. If at least two full units of effort were not completed, the catch data were not utilized for population estimates.

Each smallmouth bass and Ozark bass was weighed, and measured for total length; after a scale sample had been taken, the specimen was released into the live-well of the boat or in a net holding pen until the third unit of effort was completed. Then all specimens were returned to the sample area.

During each season, capture locations of smallmouth bass were marked with a plastic or styrofoam float attached to a lead weight. Similar procedures were followed for marking capture locations of Ozark bass during all seasons except summer 1980. At the conclusion of the last unit of effort at each site, the depth, velocity and substrate type at each site of capture was determined. Velocity was measured with a Teledyne Gurley, Model 622, Current Meter and the measurement was taken at 0.6 of the total depth. Substrate was categorized as silt, sand (< 1.6 mm diameter), pebble (1.6-12.7 mm), gravel (12.7-76.2 mm), cobble (76.2-203.2 mm), boulder (> 203.2 mm), bedrock or some combination of these categories.

During the summer of 1981, glass tubes (Gilliland, Kleinholz and Clady 1982) were used to remove the stomach contents from all fish captured during electroshocking. Contents were preserved in formalin and identified in the lab. To determine reproduction levels and food availability each site was seined during both the summer of 1980 and 1981. Young-of-the-year smallmouth bass and Ozark bass were counted and the number of each per ten seine hauls was used as an indication of reproduction. Also, the total number of species and the total number of forage fish per ten seine hauls were recorded as an indication of food availability at each site. Crayfish densities were determined by counting the number of crayfish found inside of a 1 m^2 metal sampling frame, approximately 0.2 m high. The frame was worked into the substrate and all rocks and boulders within the frame were overturned or removed until all crayfish within the grid were collected.

Population estimates were made using the depletion method described by Carle and Maughan (1980) and the maximum likelihood estimator (Carle and Strubb 1978). The 95% confidence intervals for each estimate was used to evaluate differences in population estimates between and within sites.

Densities were determined by dividing population estimates by the total area of the sample site. Standing crop, which also was calculated on a per area basis was determined by multiplying the population estimates for each site by the mean weight and then dividing by the area of the site.

Coefficients of condition or condition factors were determined from the equation $K = W \times 10^5/L^3$ (Ricker 1975) where K = Condition Factor, W = weight in grams and L = total length in millimeters. Mean condition factors were determined for both species by season, by site and by size class. Linear and curvilinear regression models were developed to determine if there were any correlations between habitat availability and condition factors, density and standing crop values that were calculated for each site for each season. Habitat parameters that were analyzed were depth, velocity, substrate composition, gradient, area in the sample area and food availability. Recreational use variables, the number of canoes passing the site during spawning and non-spawning periods, were also analyzed.

Habitat availability was determined by measuring water depth and velocity and classifying substrate types at 1-meter intervals along transects conducted perpendicular to the direction of flow. Transects were spaced at intervals of 20 to 70 meters depending on the size of the site. Measurements of depth, velocity and substrate were made with the same methods and equipment that were used to measure habitat parameters at capture locations. Each depth, velocity and substrate reading represented average values for these parameters for an area or segment 1-meter wide and extending half the distance to the next transect in both an upstream and downstream direction. Surface area for each parameter was calculated for each segment by multiplying length times width. The amount of area for each interval of depth and velocity as well as substrate type could then be determined by summing the areas of those segments that had the particular substrate type or the particular depth or velocity interval (Orth 1980). The percentage of the total area that each depth or velocity interval or substrate type comprised was calculated and used for the regression models. Percentage rather than areas were used because of the vast differences in size of sites and also because density and standing crop had already been adjusted for area. Gradients for each site were determined from 7 1/2 minute topographic maps. Canoe use was obtained from the National Park Service River Use Reports developed from rental receipts obtained from canoe and johnboat concessioners operating within the park and from onsite counts conducted by National Park Service personnel.

To compare growth of fish between sites, fish from each age group were placed in the order of descending size. To determine if fast growth was taking place, the total length of the largest fish of that age class was decreased by 5% and any fish from other sites that were larger than that total length was considered to have made exceptional growth. The total length of the shortest bass within each age class was increased by 5% and any site with fish which had a mean total length less than that value was considered to exhibit slow growth.

Growth was back-calculated from scales of Ozark bass and smallmouth bass. Scales were removed from an area below the lateral line at the depressed tip of the pectoral fin. Scales were pressed onto acetate slides (Smith 1954) and were magnified 60X using a Bausch and Lomb Microprojector. Annuli counts and measurements were made along the anterior scale radius (Paragamian 1973). Twenty percent of the 3,462 scales were read twice to verify accuracy of age assignments.

A creel census was conducted during the spring and summers by National Park Service ranger personnel as part of their regular patrol activities. Because of other duties, it was impossible to randomize dates or times of day or to devote a total day to the census. Census information was obtained from two sources. In the first, a ranger performing a river patrol recorded information from each fishing party on 1) number of fishermen in the group, 2) sex composition, 3) residence, 4) length of time fishing, 5) number and species of fish caught, 6) length and weight of smallmouth and Ozark bass in the creel, and 7) fishing methods used: boat or bank, type of rod and bait. In the second, park personnel stationed at river access points to conduct surveys on levels of canoe activity obtained the same information from each party.

Mortality for each major section and the river as a whole was calculated using a catch curve (Ricker 1975).

CHAPTER IV

RESULTS

Population Estimates

Smallmouth Bass

During the summer of 1980, population sizes of smallmouth bass at sites 1, 6, 7, 10, and 11 remained stable but populations at the remaining seven sites changed significantly over time (Table 3). Populations at sites 4 and 9 increased through the summer, those at sites 2, 3, and 8 increased and then decreased, and those at sites 5 and 12, two of the smallest sites, decreased during the summer.

Populations in summer 1981 varied even more than those in 1980. Only at sites 1 and 8 was there no significant variation between the three population estimates. Populations at sites 2 and 4 declined in late summer after remaining stable during June and July. Conversely, populations increased in late summer at sites 6 and 11 after remaining relatively constant during early and midsummer. Smallmouth bass populations at sites 5 and 12 increased throughout the summer in contrast to those at site 3 at which there was a continuous decline. At sites 7, 9, and 10, populations peaked during midsummer and then declined. Site 9 was the only one of the three sites where late summer population estimates were smaller than the initial estimate. Site 1 was the only site in which populations followed the same trend during both

Table 3. Population size estimates for smallmouth bass populations in Buffalo River, Arkansas from summer 1980 through summer 1981. Numbers in parentheses are the 95% confidence intervals for the estimates. Dashes indicate that no sample was taken. Letters by the site number give the chronological sequence in which the summer samples were taken.

Site #	Summer 1980	Fall	Winter	Spring	Summer 1981
1.a.	27 (21.0-42.8)	40 (24.0-84.9)	43 (28.0-79.3)	25 (15.0-62.5)	9 (8.0-15.0)
b.	35 (31.0-43.9)				13 (13.0-15.1)
c.	29 (25.0-38.6)				9 (8.0-15.0)
2.a.	36 (29.0-51.3)	34 (31.0-41.2)	20 (18.0-26.4)	14 (9.0-39.6)	27 (20.0-46.1)
b.	55 (42.0-78.0)				20 (20.0-21.2)
c.	34 (31.0-40.9)				17 (17.0-19.4)
3.a.	6 (6.0-7.3)	41 (33.0-56.9)	27 (25.0-32.4)	6 (6.0-7.3)	- -
b.	28 (28.0-30.3)				6 (5.0-14.3)
c.	19 (19.0-20.8)				3 (3.0-4.4)
4.a.	16 (16.0-17.8)	21 (19.0-27.6)	33 (26.0-49.1)	23 (18.0-37.6)	8 (8.0-10.1)
b.	23 (21.0-29.0)				10 (10.0-10.8)
c.	34 (26.0-52.7)				2 (2.0-4.0)
5.a.	- -	14 (14.0-15.6)	7 (7.0-10.0)	3 (3.0-5.5)	0 -
b.	27 (22.0-39.9)				1 (1.0-5.0)
c.	9 (9.0-9.9)				7 (7.0-8.7)
6.a.	57 (26.0-162.4)	40 (30.0-61.5)	143 (92.0-208.3)	38 (31.0-52.8)	3 (3.0-3.0)
b.	46 (36.0-65.1)				3 (3.0-4.4)
c.	60 (40.0-99.1)				14 (7.0-64.8)

Table 3. Continued.

Site #	Summer 1980	Fall	Winter	Spring	Summer 1981
7.a.	23 (12.0-76.4)	112 (95.0-131.1)	110 (73.0-162.2)	48 (45.0-54.4)	5 (5.0-6.5)
b.	13 (12.0-17.6)				23 (21.0-29.4)
c.	- -				8 (8.0-10.1)
8.a.	8 (8.0-9.0)	61 (53.0-73.5)	69 (23.0-294.6)	35 (28.0-50.4)	4 (4.0-5.1)
b.	59 (32.0-129.1)				5 (5.0-6.5)
c.	27 (26.0-30.4)				5 (5.0-8.2)
9.a.	38 (36.0-42.9)	- -	273 (87.0-736.9)	110 (105.0-117.1)	1 (1.0-1.0)
b.	- -				10 (9.0-16.1)
c.	158 (43.0-643.4)				0 -
10.a.	19 (14.0-36.3)	- -	19 (18.0-22.9)	25 (14.0-70.6)	2 (2.0-4.0)
b.	27 (25.0-32.8)				11 (11.0-13.0)
c.	34 (27.0-50.0)				4 (4.0-8.0)
11.a.	- -	189 (112.0-291.9)	87 (38.0-227.4)	193 (97.0-340.0)	19 (18.0-23.4)
b.	62 (41.0-105.7)				8 (6.0-20.6)
c.	75 (38.0-167.7)				42 (30.0-68.4)
12.a.	4 (4.0-5.1)		7 (7.0-7.2)	1 (1.0-2.4)	1 (1.0-1.0)
b.	3 (3.0-3.5)				3 (3.0-3.0)

summers.

All populations, except those at sites 2 and 3, had populations at the beginning of the summer of 1981 that were lower than those at the beginning of summer 1980. All three summer 1981 population estimates at sites 1, 4, 5, 9, and 10 were significantly lower than any of those from these sites during the previous summer. Sites 6, 8, 11, and 12 all started the 1981 summer with bass populations at significantly lower levels than those that were found in 1980. However, by the end of the summer population sizes did not differ significantly from at least one of the summer 1980 population estimates. At sites 2, 3, and 7 at least one 1981 population estimate was comparable to an estimate from the previous summer. At site 2, the 1981 estimate was as high as a 1980 estimate only during early summer; for sites 3 and 7, they were comparable only in midsummer. Overall, however, the summer 1981 smallmouth bass populations were lower than the populations for the same site the previous summer. By the end of summer 1981, populations at eight sites (1, 2, 3, 4, 5, 8, 9, 10) were smaller than they were at the end of summer 1980; and no site had populations that were larger.

Population estimates were obtained for nine of the twelve sites during fall 1980. The fall population estimates at five of the nine sites (1, 2, 4, 6, 11) did not differ statistically from the last summer 1980 population estimate. The remaining four sites (3, 5, 7, 8) all had higher estimates in fall than they had in the late summer. Of these four sites, site 7 showed the largest increase, approximately nine times larger. Although sites 5 and 8 had increased fall population sizes when compared to late summer levels, the fall population estimates for these two sites were not significantly different from the midsummer estimate for site 8 and was smaller than the midsummer estimate for site 5.

In the winter, population levels did not differ significantly from fall levels at sites 1, 4, 7, 8, and 11. Levels at site 6, however, increased threefold, but levels decreased at sites 2, 3, and 5. Of the three sites for which no fall samples were taken, site 9 had a population size in winter similar to that present in late summer, site 12 had an increased population compared to that in the summer, and site 10 had a winter population smaller than the one at midsummer but similar to the one in early summer.

Spring population levels did not differ significantly from those in winter at sites 1, 2, 4, 8, 9, 10 and 11. However, at sites 3, 5, 6, 7, and 12, population levels were decreased. Of the 12 sites, only at sites 1, 2, 3, and 12 were spring population levels comparable to those in early summer. At all other sites populations declined.

Ozark Bass

Population size estimates of Ozark bass also fluctuated during the summer. During summer 1980, the Ozark bass populations of site 4 increased (Table 4) but at sites 6 and 12 populations decreased. Populations at sites 2, 5, 7, 9, and 11 did not vary statistically through the summer. At the remaining sites, 1, 3, 8 and 10, populations of Ozark bass increased from early summer to midsummer but then declined.

Ozark bass populations during summer 1981 showed similar variations. However during summer 1981, populations increased at site 7, decreased at sites 2, 9, and 12, and remained stable at sites 1, 5, and 11, and increasing then decreasing at sites 3, 4, 8, and 10.

Table 4. Population estimates for Ozark bass population in Buffalo River, Arkansas from summer 1980 through summer 1981. Numbers in parentheses are the 95% confidence intervals for the estimates. Dashes indicate that no sample was taken. Letters by the site number give the chronological sequence in which the summer samples were taken.

Site #	Summer 1980	Fall	Winter	Spring	Summer 1981
1.a.	10 (10.0-12.7)	4 (4.0-6.9)	23 (21.0-29.4)	47 (43.0.54.6)	13 (11.0-21.2)
b.	24 (20.0-34.9)				13 (13.0-15.1)
c.	15 (14.0-19.5)				15 (14.0-20-0)
2.a.	27 (24.0-34.9)	27 (20.0-46.1)	32 (25.0-48.8)	16 (13.0-26.8)	49 (47.0-53.5)
b.	38 (27.0-63.8)				24 (22.0-30.1)
c.	42 (22.0-108.1)				5 (5.0-8.2)
3.a.	9 (9.0-10.9)	50 (22.0-158.4)	14 (14.0-16.4)	8 (6.0-20.6)	2 (2.0-2.8)
b.	32 (29.0-39.3)				10 (6.0-38.8)
c.	6 (6.0-7.3)				3 (3.0-5.5)
4.a.	9 (9.0-9.9)	9 (9.0-9.5)	20 (18.0-26.4)	2 (2.0-4.0)	3 (3.0-3.5)
b.	33 (26.0-49.1)				17 (13.0-31.6)
c.	30 (22.0-51.0)				2 (2.0-2.8)
5.a.	- -	22 (18.0-33.5)	3 (3.0-6.8)	25 (19.0-41.9)	48 (23.0-135.4)
b.	68 (58.0-82.6)				22 (19.0-30.9)
c.	55 (47.0-68.4)				36 (30.0-48.6)
6.a.	83 (151.9-214.1)	107 (69.0-163.5)	246 (105.0-486.9)	91 (51.0-169.1)	73 (52.0-106.9)
b.	98 (89.0-109.3)				37 (35.0-42.1)
c.	65 (60.0-73.1)				65 (49.0-91.0)

Table 4. Continued.

Site #	Summer 1980	Fall	Winter	Spring	Summer 1981
7.a.	27 (18.0-54.8)	59 (45.0-82.8)	40 (28.0-67.8)	45 (41.0-52.7)	17 (17.0-18.3)
b.	13 (12.0-18.2)				42 (30.0-68.4)
c.	- -				26 (24.0-32.0)
8.a.	32 (29.0-38.9)	74 (41.0-147.2)	78 (31.0-242.5)	56 (31.0-121.0)	16 (14.0-23.6)
b.	131 (77.0-212.4)				59 (47.0-78.8)
c.	42 (38.0-50.3)				22 (21.0-25.8)
9.a.	35 (34.0-38.7)	- -	423 (74.0-2,133.4)	55 (27.0-142.2)	48 (40.0-62.8)
b.	- -				30 (29.0-33.7)
c.	39 (36.0-45.6)				23 (22.0-27.0)
10.a.	16 (15.0-20.7)	- -	10 (8.0-20.3)	49 (31.0-91.1)	8 (8.0-10.7)
b.	44 (36.0-59.4)				29 (22.0-46.9)
c.	10 (10.0-11.2)				12 (11.0-17.0)
11.a.	- -	34 (30.0-43.5)	14 (12.0-22.2)	36 (26.0-59.8)	71 (49.0-108.6)
b.	66 (44.0-109.8)				61 (49.0-80.3)
c.	54 (50.0-61.4)				39 (34.0-49.2)
12.a.	7 (5.0-22.5)	- -	3 (3.0-3.5)	7 (7.0-10.0)	0 -
b.	0 -				0 -

During fall, population sizes at sites 2, 6, and 8 were stable compared to those present in late summer, but those at sites 3 and 7 increased and those at sites 1, 4, 5, and 11 decreased.

During the winter, population estimates for sites 2, 6, 7, and 8 were not significantly different than those for fall; however, increased population levels occurred at sites 1 and 4 with decreased populations at sites 3, 5, and 11. Winter data from the three sites at which no fall samples were taken were compared with those from late summer. Population levels increased at sites 9 and 12 and showed no change at site 10.

Only at site 4 was the spring population level lower than that found in winter. At sites 2, 3, 6, 7, 8, and 9, populations did not change significantly and at sites 1, 5, 10, 11, and 12 populations increased.

Except at site 2, the Ozark bass populations in summer 1981 were either the same as those present in spring (sites 4, 5, 6, 9, and 11) or lower (sites 1, 3, 7, 8, 10, and 12).

Density

Smallmouth Bass

Densities of smallmouth bass fluctuated from a seasonal mean high of 46.8 bass/ha (Table 5) during the fall to a low of 11.8 bass/ha during summer 1981.

Site 2 had the highest density of any site during every season except winter and site 1 had the second highest density during every season. The range of densities encountered between sites during each season was generally wide, especially during the summer of 1980 when site 2 had a mean density of 143.7 bass/ha and site 10 had only 7.0 bass/ha.

Ozark Bass

Mean densities ranged from a high of 45.7 bass/ha during winter to a low of 22.3 bass/ha during summer 1981 (Table 5). Densities at site 2 followed by those at sites 5 and 6, were the highest during both summers and fall. During winter, densities at site 6, followed by those at sites 9 and 12, were highest (150.1 bass/ha). In spring, site 1 with 87.0 Ozark bass/ha had the highest density of all sites. There was high variability in density levels between sites within the same season; the greatest range in densities occurred during winter when densities ranged from a high of 150.1 bass/ha at site 6 to a low of 1.9/ha at site 11.

Standing Crop

Smallmouth Bass

The mean standing crop of smallmouth bass was highest (5.8 kg/ha) in the summer of 1980 (Table 6, Appendix D). Levels declined to 3.9 kg/ha in the fall, rose to 5.0 kg/ha in the winter then declined through spring and summer 1981. The summer 1981 mean standing crop of 1.9 kg/ha was 67% lower than the mean standing crop of the previous summer.

Site 2 had the highest standing crop during both summers and in the spring, but site 9 had the highest standing crop during the winter. The highest standing crop at site 2 was 23.2 kg/ha and occurred during summer 1980.

Table 5. Seasonal densities (N/ha) of smallmouth bass and Ozark bass in Buffalo River, Arkansas for each season.

Site number	Season				
	Summer 1980	Fall	Winter	Spring	Summer 1981
			Smallmouth bass		
1	56.2	74.1	79.6	46.3	19.2
2	143.7	117.2	69.0	48.3	73.6
3	18.6	43.2	28.4	6.3	4.8
4	26.2	22.6	35.5	24.7	7.2
5	25.4	19.7	9.9	4.2	3.8
6	33.3	24.5	87.7	23.3	4.1
7	10.0	61.9	60.8	26.5	6.3
8	16.3	31.8	35.9	18.2	2.4
9	26.6	-	74.2	29.9	1.0
10	7.0	-	5.0	6.5	1.5
11	9.4	25.8	11.9	26.4	3.1
12	27.0	-	53.8	7.7	15.4
$\bar{x}$	33.0	46.8	46.0	22.4	11.8
			Ozark bass		
1	30.2	7.4	42.6	87.0	25.3
2	123.0	93.1	110.3	55.2	89.7
3	16.5	52.6	14.7	8.4	5.3
4	25.8	9.7	21.5	2.2	7.9
5	86.7	31.0	4.2	35.2	49.8
6	70.8	65.6	150.1	55.8	35.8
7	11.1	32.6	22.1	24.9	15.7
8	35.6	38.5	40.6	29.2	16.8
9	10.1	-	115.0	15.0	9.2
10	6.1	-	2.6	12.8	4.3
11	8.2	4.6	1.9	4.9	7.8
12	27.0	-	23.1	53.9	0.0
$\bar{x}$	37.6	37.2	45.7	32.0	22.3

Table 6. Seasonal standing crops (kg/ha) of smallmouth bass and Ozark bass in Buffalo River, Arkansas.

Site number	Season				
	Summer 1980	Fall	Winter	Spring	Summer 1981
			Smallmouth bass		
1	9.8	10.5	6.6	3.7	4.8
2	23.2	8.2	1.2	14.4	10.2
3	4.1	3.4	4.4	1.8	0.2
4	4.2	2.8	2.5	7.3	2.8
5	4.6	1.6	0.2	0.7	0.4
6	6.5	2.1	10.1	0.7	0.3
7	1.4	3.6	2.4	1.5	0.6
8	3.0	1.6	6.1	1.2	0.2
9	6.4	–	19.0	5.9	0.4
10	1.6	–	1.4	0.3	0.1
11	1.2	1.9	0.3	1.3	0.3
12	3.0	–	5.7	0.6	2.6
$\bar{x}$	5.7	3.9	5.0	3.3	1.9
			Ozark bass		
1	3.8	0.9	5.5	11.2	3.0
2	12.6	4.9	2.5	5.9	11.7
3	1.6	5.4	0.8	1.2	0.5
4	2.9	0.7	0.9	0.5	0.8
5	11.0	3.0	0.1	4.1	4.8
6	7.9	7.2	12.1	3.5	3.2
7	1.3	3.8	0.9	3.0	1.4
8	3.0	2.9	1.3	1.7	1.6
9	1.2	–	12.7	1.6	0.8
10	0.6	–	0.4	1.8	0.4
11	0.8	0.4	0.1	0.3	0.5
12	0.9	–	1.5	3.1	0.0
$\bar{x}$	4.0	3.3	3.2	3.1	2.4

Ozark Bass

The mean standing crop of Ozark bass was highest (4.0 kg/ha) during the summer of 1980 (Table 6). There was a gradual decline with each subsequent season until a low of 2.4 kg/ha was reached during summer 1981.

Summer standing crops were highest at sites 2 and 5; however values at site 2 remained close to the summer 1980 level during 1981, whereas site 5 was over 50% lower during the second summer. Site 6 had the highest fall standing crop and along with site 9, the highest winter standing crop also. In spring, site 1 had a standing crop nearly double that of the next highest. The highest overall standing crop occurred at site 9 during winter with 12.8 kg/ha, with the second highest of 12.6 kg/ha at site 2 during summer 1980.

Habitat Utilization

Depth

Smallmouth Bass. Depths utilized by smallmouth bass varied by season (Table 7). Fish moved from shallow water, mean depth of 0.80 m, to progressively deeper water from fall (0.88 m) to winter (1.04 m) to spring (1.11 m). A chi square test of independence showed a significant difference in depth utilization by season (Table 8). The only exceptions to these differences occurred in the comparisons between summer 1980 and summer 1981 and between fall and summer 1981.

Ozark Bass. Only during winter and summer 1981 was there a sufficient sample size to allow evaluation of depth utilization. Depths used were shallowest (mean = 0.79 m) during the summer (Table 9). As

Table 7. Seasonal frequency of occurrence and percentage of total captures of smallmouth bass at various depth intervals.

Depth (m)	Summer 1980		Fall 1980		Winter 1980		Spring 1981		Summer 1981	
	N	% of Total	N	% of Total	N	% of Total	N	% of Total	N	% of Total
0.00-0.25	15	2.0	3	0.8	1	0.5	0	0.0	2	1.2
0.26-0.50	143	18.8	42	11.2	9	4.8	5	3.0	27	15.6
0.51-0.75	241	31.7	98	26.1	28	15.0	25	15.3	44	25.4
0.76-1.00	160	21.1	114	30.4	61	32.6	30	18.3	48	27.7
1.01-1.25	116	15.2	73	19.5	40	21.4	51	31.1	30	17.4
1.26-1.50	66	8.7	32	8.5	29	15.5	28	17.1	15	8.7
1.51-1.75	17	2.2	10	2.7	9	4.9	20	12.2	5	2.8
1.76-2.00	2	0.3	3	0.7	6	3.2	3	1.8	2	1.2
2.01-2.25	0	0.0	0	0.0	4	2.1	1	0.6	0	0.0
2.26-2.50	0	0.0	0	0.0	0	0.0	1	0.6	0	0.0
Total	760	100.0	375	100.0	187	100.0	164	100.0	173	100.0
Range (m)	0.09-1.95 m		0.18-1.79 m		1.25-2.13 m		0.33-2.50 m		0.18-1.98 m	
Mean (m)	0.80 m		0.88 m		1.04 m		1.11 m		0.84 m	

Table 8. Seasonal chi square values, degrees of freedom and probability values for tests of differences in depth distribution of A) smallmouth bass, B) Ozark bass, and C) smallmouth bass and Ozark bass.

Seasons compared	X^2 Value	Degrees of freedom	Probability (P)
	Smallmouth bass		
Summer 1980 - Fall 1980	27.53	7	$P < 0.005$
Summer 1980 - Winter 1980	91.00	8	$P < 0.005$
Summer 1980 - Spring 1981	115.83	9	$P < 0.005$
Summer 1980 - Summer 1981	9.49	7	$^*P > 0.100$
Fall 1980 - Winter 1980	33.03	8	$P < 0.005$
Fall 1980 - Spring 1981	58.71	9	$P < 0.005$
Fall 1980 - Summer 1981	2.75	7	$^*P > 0.900$
Winter 1980 - Spring 1981	20.69	9	$P < 0.025$
Winter 1980 - Summer 1981	27.05	8	$P < 0.005$
Spring 1981 - Summer 1981	46.83	9	$P < 0.005$
	Ozark bass		
Winter 1980 - Summer 1981	74.23	7	$P < 0.005$
	Smallmouth bass and Ozark bass		
Summers 1981	10.68	8	$^*P > 0.100$
Winters 1980	20.81	7	$P < 0.500$

* Not significant at 0.05.

Table 9. Frequency of occurrence and percentage of total captures of Ozark bass at various depth intervals during winter 1980 and summer 1981.

Depth (m)	Winter 1980 N	Winter 1980 % of Total	Summer 1981 N	Summer 1981 % of Total
0.00-0.25	2	1.8	9	1.8
0.26-0.50	2	1.8	93	18.8
0.51-0.75	26	23.2	139	28.2
0.76-1.00	28	25.0	133	26.9
1.01-1.25	18	16.1	83	16.8
1.26-1.50	21	18.7	30	6.1
1.51-1.75	15	13.4	6	1.2
1.76-2.00	0	0.0	1	0.2
Total	112	100.0	494	100.0
Range (m)	0.15-1.63		0.15-1.77	
Mean (m)	1.03		0.79	

with smallmouth bass, deeper waters were used in winter (mean preferred depth = 1.06 m).

Velocity

Smallmouth Bass. Water velocity measurements were taken over a period of five seasons (Table 10) and chi square tests of independence (Table 11) indicated that there was significant seasonal differences in the velocities utilized by smallmouth bass.

Smallmouth bass occurred in a wide range of velocities during the summer of 1981 when captures were made in velocities up to 104 cm/s. However, they used the highest velocities (mean: 20.5 cm/s) in the spring. During summer 1980, smallmouth bass generally utilized areas of the river without current; 64.8% of all captures occurred in areas with a 0 cm/s velocity and 7.8% of all smallmouth bass were captured in velocities of 5 cm/s or less. In the fall, bass moved into slightly faster velocities than they preferred in the previous summer (1980); in winter, they selected even higher velocities.

From summer 1980 through spring 1981, there was a trend for smallmouth bass to increase the range of velocities occupied with each progressive season. During 1981, bass occupied a wider range of velocities than in summer 1980. In 1980, the mean capture velocity was 4.0 cm/s but in 1981 it was 11.9 cm/s. In 1981, the median velocity was 7 cm/s compared to 0 cm/s in 1980. Velocities utilized in the summer of 1981 were intermediate between those utilized in winter and spring.

Ozark Bass. Data on Ozark bass habitat preference was taken only during winter and summer 1981 (Table 12). The chi square test of independence indicated that there was a significant difference between velocities utilized by Ozark bass in winter and those utilized during summer (Table 11). Both the mean and median velocities utilized in summer, 60 cm/s and 10.2 cm/s respectively, were nearly double those utilized in winter, 3.0 cm/s and 5.4 cm/s. Ozark bass in winter seemed to prefer lower velocities than they did in summer.

Substrate

Smallmouth Bass. During summer 1980, the largest percentage (16.4%) of all smallmouth bass captures occurred over bedrock (Appendix E, Table 57). Utilization of cobble-boulder (11.7%), boulder-bedrock (11.0%) and boulder (10.5%) were the nest highest. When the 42 possible combinations of substrate types were combined into nine broad categories (Table 13) and reanalyzed, boulder was the most preferred substrate; with 45.2% of all smallmouth bass captures occurring over this substrate. Bedrock (37.3%) and cobble (29.3%) were the next most common substrates at sites of capture. Detritus was the least preferred substrate (1.4%). Silt was a substrate occurred at only 14.5% of all capture locations and in 73 of the 110 captures at those locations, it occurred only as a light covering over cobble, boulder, or bedrock.

In fall, the largest percentage of smallmouth bass were found over bedrock (24.7%) with boulder-bedrock the second most preferred substrate and cobble-boulder the third. Bedrock was also the preferred substrate when the individual substrates were combined; nearly 60% of all smallmouth bass captured during the fall were found over bedrock or some bedrock combination.

Although the preferred substrate types (bedrock, boulder-bedrock, and cobble-boulder) remained the same in winter as in fall; there was a reduction in the use of these substrates and a greater frequency of occurrence of smallmouth bass over silt and sand. These changes probably reflect the movement of bass into deeper, lower-velocity water during the winter. Winter was the only season that bass were not captured over detritus and may indicate that bass only forage over detrital covered areas.

In spring, boulder-bedrock became the preferred substrate with 26.8% of all smallmouth bass being captured over this substrate type. Bedrock was second and boulder was third in utilization. Overall, use of boulder equaled that of bedrock in the combined substrate categories but use of cobble and silt substrates decreased.

Habitat preferences in summer 1981 (Table 13) were not the same as those observed during the previous summer ($P < 0.005$) and in fact substrate use in each season differed significantly from that in any other season (Table 14).

During summer 1981, cobble-boulder (Table 14) was the most common substrate used by smallmouth bass, with 20.9% of all captures occurring over this substrate type. Bedrock use was only 12.8%, boulder only 11.1% and boulder-bedrock was 9.3%. When all 42 substrate combinations were reduced to nine substrate categories, cobble (37.8%) and boulder (36.0%) were the two most important substrate categories followed in importance by bedrock (26.2%) and gravel (20.1%). The major difference between summer 1980 and 1981 was that in 1981 smallmouth bass were less restricted to boulder and bedrock substrates and more evenly used gravel, cobble, boulder and bedrock.

<u>Ozark Bass</u>. During the winter, most Ozark bass used bedrock and boulder substrates (Table 15, Appendix E, Table 58). In summer 1981,

Table 10. Seasonal frequency of occurrence and percentage of total captures of smallmouth bass at different water velocities.

Velocity (cm/s)	Summer 1980		Fall 1980		Winter 1980		Spring 1981		Summer 1981	
	N	% of Total	N	% of Total	N	% of Total	N	% of Total	N	% of Total
0	416	64.8	42	21.4	64	35.0	8	4.9	46	26.6
1-5	77	12.0	66	33.7	44	24.0	19	11.6	25	13.3
6-10	58	9.0	43	22.0	27	14.8	23	14.0	38	22.0
11-15	42	6.5	21	10.7	21	11.5	30	18.3	16	9.3
16-20	21	3.3	7	3.6	11	6.0	18	11.0	13	7.6
21-25	8	1.3	9	4.6	5	2.7	17	10.4	13	7.5
26-30	3	0.5	1	0.5	2	1.1	10	6.1	2	1.2
31-35	6	0.9	2	1.0	5	2.7	8	4.9	9	5.2
36-40	4	0.8	0	0	2	1.1	14	8.5	2	2.3
41-45	2	0.5	2	1.0	0	0	3	1.8	1	0.6
46-50	2	0.3	0	0	1	0.5	3	1.8	5	2.9

Table 10. Continued.

Velocity (cm/s)	Summer 1980 N	Summer 1980 % of Total	Fall 1980 N	Fall 1980 % of Total	Winter 1980 N	Winter 1980 % of Total	Spring 1981 N	Spring 1981 % of Total	Summer 1981 N	Summer 1981 % of Total
51+	3	0.3	3	1.5	1	0.5	11	6.7	3	1.7
Total	642		196		183		164		173	
Median (cm/s)	0		5		5		17		7	
Mean (cm/s)	4.0		4.7		7.3		20.5		11.9	
Range (cm/s)	0-72		0-57		0-54		0-73		0-104	
25% title (cm/s)	0		3		0		8		0	
75% tile (cm/s)	5		9		11		27		17	

Table 11. Seasonal chi-square values, degrees of freedom and probability values of tests of differences in water velocity distribution of A) smallmouth bass, B) Ozark bass, C) smallmouth bass and Ozark bass.

Seasons compared	X^2 Value	Degrees of freedom	Probability (P)
	Smallmouth bass		
Summer 1980 - Fall 1980	129.7	11	$P < 0.005$
Summer 1980 - Winter 1980	55.5	11	$P < 0.005$
Summer 1980 - Spring 1981	278.5	11	$P < 0.005$
Summer 1980 - Summer 1981	111.7	11	$P < 0.005$
Fall 1980 - Winter 1980	21.2	11	$P < 0.005$
Fall 1980 - Spring 1981	94.6	11	$P < 0.005$
Fall 1980 - Summer 1981	33.6	11	$P < 0.005$
Winter 1980 - Spring 1981	90.1	11	$P < 0.005$
Winter 1980 - Summer 1981	20.0	11	$P < 0.005$
Spring 1981 - Summer 1981	56.9	11	$P < 0.005$
	Ozark bass		
Winter 1980 - Summer 1981	24.3	11	$P < 0.025$
	Smallmouth bass and Ozark bass		
Summers 1981	26.2	11	$P < 0.010$
Winters 1980	9.1	11	*$P > 0.500$

* Not significant at 0.05.

Table 12. Frequency of occurrence and percentage of total captures of Ozark bass at different water velocities during winter 1980 and summer 1981.

Velocity (cm/s)	Winter 1980		Summer 1981	
	N	% of Total	N	% of Total
0	48	42.9	171	34.7
01-05	22	19.6	66	13.4
06-10	24	21.4	75	15.2
11-15	10	8.9	60	12.2
16-20	3	2.7	26	5.3
21-25	1	0.9	32	6.5
26-30	1	0.9	21	4.3
31-35	1	0.9	13	2.6
36-40	1	0.9	13	2.6
41-45	0	0.0	7	1.4
46-50	1	0.9	1	0.2
51+	0	0.0	8	1.6
Total	112	100.0	493	100.0
Median (cm/s)	3		6	
Mean (cm/s)	5.4		10.2	
Range (cm/s)	0-47		0-60	
25% tile (cm/s)	0		0	
75% tile (cm/s)	8		14	

velocities utilized by Ozark bass in winter and those utilized during summer (Table 11). Both the mean and median velocities utilized in summer, 60 cm/s and 10.2 cm/s respectively, were nearly double those utilized in winter, 3.0 cm/s and 5.4 cm/s. Ozark bass in winter seemed to prefer lower velocities than they did in summer.

Substrate

Smallmouth Bass. During summer 1980, the largest percentage (16.4%) of all smallmouth bass captures occurred over bedrock (Appendix E, Table 57). Utilization of cobble-boulder (11.7%), boulder-bedrock (11.0%) and boulder (10.5%) were the nest highest. When the 42 possible combinations of substrate types were combined into nine broad categories (Table 13) and reanalyzed, boulder was the most preferred substrate; with 45.2% of all smallmouth bass captures occurring over this substrate. Bedrock (37.3%) and cobble (29.3%) were the next most common substrates at sites of capture. Detritus was the least preferred substrate (1.4%). Silt was a substrate occurred at only 14.5% of all capture locations and in 73 of the 110 captures at those locations, it occurred only as a light covering over cobble, boulder, or bedrock.

In fall, the largest percentage of smallmouth bass were found over bedrock (24.7%) with boulder-bedrock the second most preferred substrate and cobble-boulder the third. Bedrock was also the preferred substrate when the individual substrates were combined; nearly 60% of all smallmouth bass captured during the fall were found over bedrock or some bedrock combination.

Although the preferred substrate types (bedrock, boulder-bedrock, and cobble-boulder) remained the same in winter as in fall; there was a reduction in the use of these substrates and a greater frequency of occurrence of smallmouth bass over silt and sand. These changes probably reflect the movement of bass into deeper, lower-velocity water during the winter. Winter was the only season that bass were not captured over detritus and may indicate that bass only forage over detrital covered areas.

In spring, boulder-bedrock became the preferred substrate with 26.8% of all smallmouth bass being captured over this substrate type. Bedrock was second and boulder was third in utilization. Overall, use of boulder equaled that of bedrock in the combined substrate categories but use of cobble and silt substrates decreased.

Habitat preferences in summer 1981 (Table 13) were not the same as those observed during the previous summer ($P < 0.005$) and in fact substrate use in each season differed significantly from that in any other season (Table 14).

During summer 1981, cobble-boulder (Table 14) was the most common substrate used by smallmouth bass, with 20.9% of all captures occurring over this substrate type. Bedrock use was only 12.8%, boulder only 11.1% and boulder-bedrock was 9.3%. When all 42 substrate combinations were reduced to nine substrate categories, cobble (37.8%) and boulder (36.0%) were the two most important substrate categories followed in importance by bedrock (26.2%) and gravel (20.1%). The major difference between summer 1980 and 1981 was that in 1981 smallmouth bass were less restricted to boulder and bedrock substrates and more evenly used gravel, cobble, boulder and bedrock.

Ozark Bass. During the winter, most Ozark bass used bedrock and boulder substrates (Table 15, Appendix E, Table 58). In summer 1981,

Table 13. Seasonal frequency of occurrence and percentage of total captures of smallmouth bass over various substrate types in Buffalo River, Arkansas.

Substrate	Summer 1980		Fall 1980		Winter 1980		Spring 1981		Summer 1981	
	N	% of Total	N	% of Total	N	% of Total	N	% of Total	N	% of Total
Silt	110	14.5	61	16.4	44	23.7	20	12.2	16	9.3
Sand	34	4.5	5	1.3	9	4.8	15	9.1	12	7.0
Pebble	44	5.8	7	1.9	3	1.7	16	9.8	7	4.1
Gravel	137	18.0	67	18.0	18	10.0	11	6.7	36	20.1
Cobble	223	29.3	102	27.4	47	25.3	30	18.3	65	37.8
Boulder	344	45.2	159	42.7	73	39.2	87	53.0	62	36.0
Bedrock	284	37.3	222	59.7	102	54.8	86	52.4	45	26.2
Detritus	11	1.4	4	1.1	0	0	8	4.9	4	2.3
Vegetation	17	2.2	1	0.3	4	2.2	3	1.8	9	5.2
Total	761		372		186		164		172	

Table 14. Seasonal chi-square values, degrees of freedom and probability values of tests of differences in substrate distribution of A) smallmouth bass, B) Ozark bass, and C) smallmouth bass and Ozark bass.

Seasons compared	X^2 Value	Degrees of freedom	Probability (P)
	Smallmouth bass		
Summer 1980 - Fall 1980	48.5	8	$P < 0.005$
Summer 1980 - Winter 1980	35.1	8	$P < 0.005$
Summer 1980 - Spring 1981	41.1	8	$P < 0.005$
Summer 1980 - Summer 1981	24.1	8	$P < 0.005$
Fall 1980 - Winter 1980	23.7	8	$P < 0.005$
Fall 1980 - Spring 1981	65.8	8	$P < 0.005$
Fall 1980 - Summer 1981	69.3	8	$P < 0.005$
Winter 1980 - Spring 1981	34.5	8	$P < 0.005$
Winter 1980 - Summer 1981	50.0	8	$P < 0.005$
Spring 1981 - Summer 1981	51.1	8	$P < 0.005$
	Ozark bass		
Winter 1980 - Summer 1981	14.5	8	*$0.05 < P < 0.10$
	Smallmouth bass and Ozark bass		
Summers 1981	32.9	8	$P < 0.050$
Winters 1980	6.3	8	*$P < 0.500$

* Not significant at 0.05.

Table 15. Frequency of occurrence and percentage of total captures of Ozark bass over different substrate types during winter 1980 and summer 1981.

	Winter 1980		Summer 1981	
Substrate	N	% of Total	N	% of Total
Silt	18	18.0	36	7.3
Sand	3	3.0	17	3.4
Peble	2	2.0	23	4.7
Gravel	11	11.0	52	11.2
Cobble	30	30.0	96	19.7
Boulder	41	41.0	213	43.2
Bedrock	46	46.0	168	34.9
Detritus	1	1.0	5	1.0
Vegetation	4	4.0	31	6.3

boulder became the most preferred substrate.

Coefficient of Condition

Smallmouth Bass

Definite seasonal variation occurred in the coefficient of condition, K, of smallmouth bass in the Buffalo River. The overall mean K value was highest during the summer of 1980 (1.45) (Table 16). Following this high, the condition of the population declined with each season until it reached a low of 1.13 during the winter. The coefficient of condition then increased during the spring and summer of 1981. However, the condition factor for the summer 1981 population (1.28), was not as high as that for the population in the previous summer. In fact, the condition of the bass in summer 1981 was comparable to that found the previous fall. It should be also noted that the condition in spring was not as high as in the fall.

Except for those bass less than 100 mm, condition factors tended to increase with length (Table 17) from fall 1980 to summer 1981. During summer 1980, K decreased with increasing length. For the period from fall to summer 1981, bass between 101 and 200 mm were in poorer condition than bass in larger or smaller length classes.

Smallmouth bass at site 7 were in much better condition than bass at other sites during both summers (Figure 3, Appendix F). The diffeence between site 7 and other sites was not as great during summer 1980 as it was in 1981. During fall and spring, bass at site 6 exhibited the highest K values, although rather high K values also occurred at sites 1 and 5 during fall. Condition factors at site 10 averaged 1.77 during winter and at that time were much higher than

Table 16. Seasonal coefficients of condition, K, for smallmouth bass and Ozark bass in Buffalo River, Arkansas.

Species	Season	Sample size	K	95% Confidence interval
Smallmouth bass	Summer 1980	709	1.45	1.39 - 1.51
	Fall 1980	542	1.33	1.27 - 1.39
	Winter 1980	440	1.13	1.11 - 1.15
	Spring 1981	372	1.19	1.17 - 1.21
	Summer 1981	275	1.28	1.22 - 1.34
Ozark bass	Summer 1980	1092	2.16	2.10 - 2.22
	Fall 1980	287	1.94	1.86 - 2.02
	Winter 1980	340	1.74	1.70 - 1.78
	Spring 1981	300	1.93	1.89 - 1.97
	Summer 1981	791	2.03	1.87 - 2.19

Table 17. Condition factors, K, by size and season for smallmouth bass in Buffalo River, Arkansas. Numbrs in parentheses represent the 95% confidence intervals for the mean.

Total length (mm)	Season				
	Summer 1980	Fall	Winter	Spring	Summer 1981
51-100	2.17 N=115 (1.89-2.45)	1.98 N=94 (1.76-2.20)	1.22 N=99 (1.14-1.30)	1.30 N=94 (1.22-1.38)	1.30 N=36 (1.10-1.50)
101-150	1.53 N=110 (1.40-1.66)	1.13 N=179 (1.07-1.19)	1.02 N=129 (0.98-1.06)	1.09 N=118 (1.05-1.13)	1.12 N=64 (1.06-1.18)
151-200	1.35 N=103 (1.27-1.43	1.22 N=106 (1.16-1.28)	1.08 N=93 (1.06-1.10)	1.15 N=66 (1.09-1.21)	1.14 N=42 (1.08-1.20)
201-250	1.24 N=155 (1.20-1.28)	1.24 N=69 (1.18-1.30)	1.20 N=35 (1.14-1.26)	1.15 N=32 (1.07-1.23)	1.19 N=59 (1.13-1.25)
251-300	1.23 N=121 (1.20-1.26)	1.24 N=55 (1.20-1.28)	1.14 N=39 (1.10-1.18)	1.23 N=25 (1.17-1.29)	1.24 N=30 (1.20-1.28)
301-350	1.24 N=69 (1.19-1.29)	1.29 N=32 (1.21-1.37)	1.28 N=21 (1.22-1.34)	1.29 N=17 (1.23-1.35)	1.18 N=16 (1.01-1.35)
351-400	1.24 N=22 (1.20-1.28)	1.19 N=3 (0.89-1.49)	1.30 N=13 (1.17-1.43	1.39 N=11 (1.30-1.48)	1.35 N=4 (1.25-1.45)

Table 17. Continued.

Total length (mm)	Season				
	Summer 1980	Fall	Winter	Spring	Summer 1981
401-450	1.30 N=15 (1.23-1.37)	1.40 N=1 -	1.13 N=5 (1.06-1.56)	1.44 N=7 (1.24-1.64)	1.31 N=8 (1.22-1.40)
451-500	1.27 N=8 (1.18-1.36)	1.38 N=2 (0.87-1.89)	1.37 N=6 (1.29-1.95)	1.30 N=2 (0.79-1.81)	1.35 N=1 -

The high K values calculated for bass less than 100 mm TL during summer 1980 and fall was due to sampling error in measuring the weight of small bass. The inaccuracies were corrected by the use of a scale that was more accurate for smaller fish during the remaining three seasons.

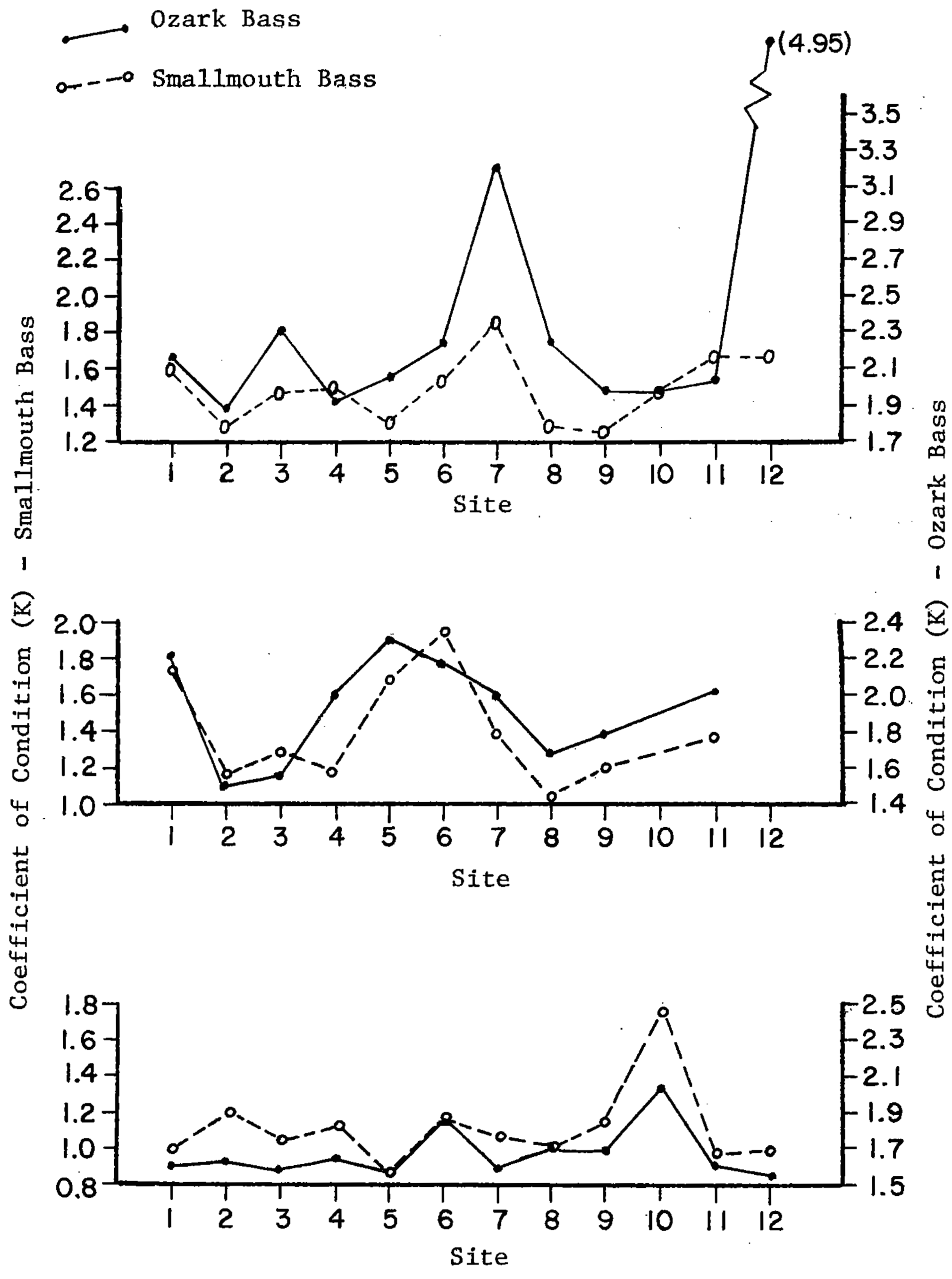

Figure 3. Variation in coefficient of condition, K, for smallmouth bass and Ozark bass by season and site for Buffalo River, Arkansas from summer 1980 to summer 1981.

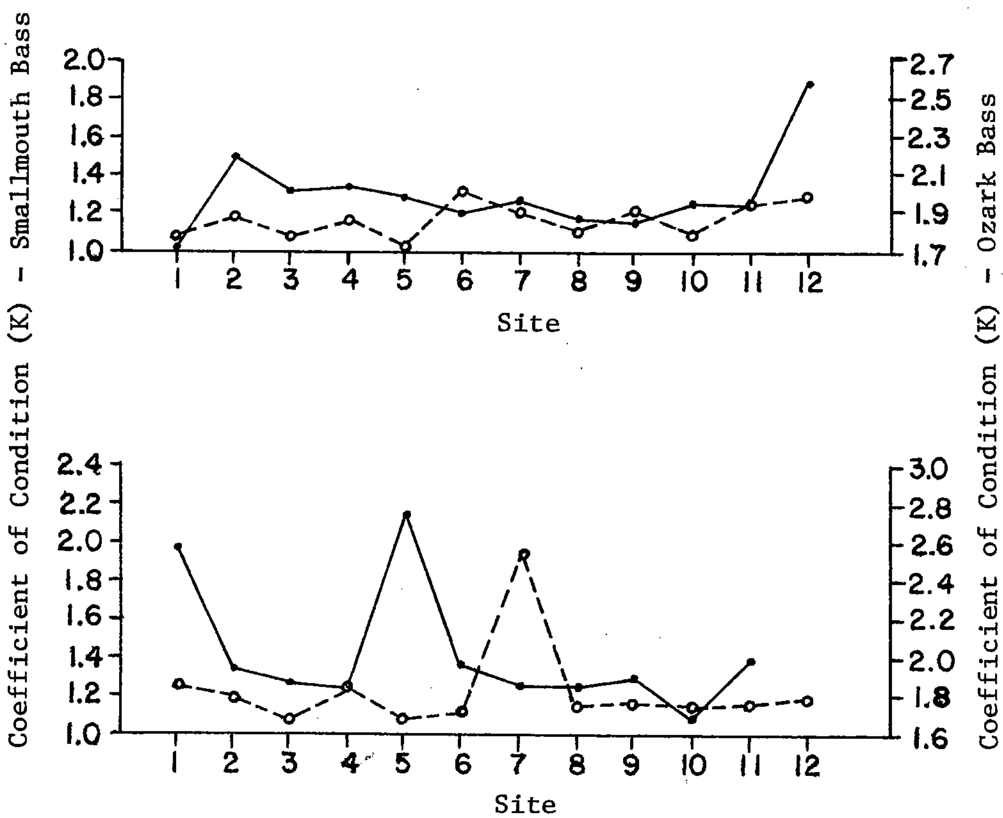

Figure 3. Continued.

those at the other sites.

Ozark Bass

The highest K values for Ozark bass occurred in summer; the lowest occurred in winter (Table 16). Unlike K values in smallmouth bass however, spring condition coefficients were very similar to those in the fall.

There was no trend in Ozark bass for K to increase with length or size as there was with smallmouth bass (Table 18). During both summers, the 51-100 mm size-group had a higher K than any other group; however in the winter, bass in the size range of 51 mm to 150 mm had the lowest K. All size classes in the summer of 1981 had lower K than similar size classes of summer 1980. The largest differences occurred in Ozark bass less than 201 mm TL.

During the summer of 1980, fish at sites 7 and 12 were the only ones with better than average K factors (Figure 3). During summer 1981, fish at sites 1 and 5 were in better condition and those at site 7 were in poorer condition than fish at other sites. Site 5 also had a high K factor in the fall as did sites 1 and 6. During the winter, site 10 had the higher K factor of any site, just as it did for smallmouth bass. Seasonal K factors for Ozark bass for each site are provided in Apprndix F for Ozark bass.

Age and Growth

Smallmouth Bass

Growth rates for smallmouth bass from summer 1981 were slower than those from summer 1980 (Table 19, Appendix G). In addition, growth

Table 18. Condition factors, K, by size and season for Ozark bass in Buffalo River, Arkansas. Numbers in parentheses represent the 95% confidence intervals for the mean.

Total length (mm)	Season: Summer 1980	Fall	Winter	Spring	Summer 1981
< 51	-	1.46 N=2	2.05 N=1	2.37 N=9	3.08 N=5
	-	(0.06-2.86)		(1.77-2.97)	(0.92-5.24)
51-100	3.47 N=118	2.05 N=48	1.69 N=125	1.96 N=71	2.10 N=134
	(3.11-3.83)	(1.81-2.29)	(1.61-1.77)	(1.86-2.06)	(1.94-2.26)
101-150	2.07 N=235	1.95 N=63	1.64 N=60	1.79 N=47	1.85 N=251
	(1.95-2.19)	(1.73-2.17)	(1.58-1.70)	(1.71-1.87)	(1.75-1.95)
151-200	1.96 N=499	1.92 N=113	1.79 N=96	1.91 N=103	1.86 N=222
	(1.94-1.98)	(1.84-2.00)	(1.77-1.81)	(1.87-1.95)	(1.82-1.90)
201-250	1.92 N=226	1.92 N=57	1.83 N=56	1.94 N=66	1.89 N=165
	(1.88-1.96)	(1.84-2.00)	(1.73-1.93)	(1.86-2.02)	(1.87-1.91)
251-300	1.98 N=12	1.75 N=4	2.07 N=2	2.00 N=4	1.84 N=11
	(1.78-2.18)	(1.02-2.48)	(0.00-4.23)	(1.71-2.29)	(1.51-2.17)

Table 19. Size at age of smallmouth bass as calculated from seasonal catch data in Buffalo River, Arkansas. Sample size is in parentheses.

Season	Mean calculated total length (mm) at each annulus							
	I	II	III	IV	V	VI	VII	VIII
Summer 1980	125.5	178.6	229.0	275.2	328.2	360.8	407.1	449.9
	(472)	(374)	(237)	(99)	(41)	(18)	(7)	(1)
Fall 1980	130.1	179.2	228.7	269.1	316.6	376.8	413.0	
	(271)	(188)	(97)	(35)	(5)	(3)	(3)	
Winter 1980	100.5	155.0	217.7	271.9	343.4	394.1	423.6	445.9
	(210)	(140)	(75)	(31)	(8)	(2)	(3)	(3)
Spring 1981	99.4	159.1	214.0	273.3	317.5	383.6	424.4	
	(187)	(120)	(68)	(38)	(15)	(6)	(1)	
Summer 1981	95.0	150.9	201.0	237.8	295.3	355.6	384.7	406.7
	(174)	(108)	(79)	(37)	(23)	(6)	(1)	(1)

rates for ages I, II and III fish from winter and spring were slower than those for summer 1980 and fall.

Sufficient data for comparing growth rates between sites were available only for the summer of 1980. Age I fish from sites 7, 4, 8, 2, and 12 grew the least (Table 20) and those from sites 9, 10, 5, 6, 11, and 1 grew the fastest. Growth at all sites exceeded the North American average cited by Carlander (1977). For age III fish, slowest growth occurred at sites 4 and 3, whereas growth at sites 5, 9, 10, and 6 was faster than at other sites on the river as well as being faster than the national avaerage. For age V fish, growth at site 4 was the slowest whereas that at sites 8, 6, and 7 was the fastest.

Ozark Bass

Growth rates in all age classes of Ozark bass were greater in summer 1981 (Table 21) than in summer 1980. This was the opposite of what occurred in smallmouth bass populations.

During summer 1980, growth at sites 1, 5, 7, 10, and 11 was the fastest (Table 22) whereas that at sites 8 and 6 was the slowest. However, slow growth at site 6 continued only through age V. Only a few Ozark bass were available for age and growth analysis from Calf Creek. Those fish, however, had much slower growth than those from locations on the main river.

During summer 1981, Ozark bass at sites 10, 6, and 5 (Table 23) had the fastest overall growth rates and those from sites 1 and 3 had The slowest. However, growth of fish at site 5 was slow for fish of ages I and II.

Another anomaly also occurred in the data at site 1. In 1980, fish

Table 20. Size at age of smallmouth bass as determined from fish caught during the summer of 1980 at 12 sites in Buffalo River, Arkansas. Sample size is in parentheses.

Site	Mean calculated total length (mm) at each annulus							
	I	II	III	IV	V	VI	VII	VIII
1	128 (59)	174 (50)	222 (32)	246 (11)	317 (3)	340 (1)	382 (1)	
2	120 (63)	164 (46)	218 (21)	292 (6)	344 (5)	370 (2)		
3	124 (39)	174 (39)	212 (29)	262 (14)	324 (5)	378 (1)	421 (1)	
4	118 (44)	159 (34)	207 (20)	240 (6)	300 (3)	362 (2)	430 (2)	
5	131 (22)	195 (15)	260 (12)					
6	129 (51)	186 (40)	238 (23)	286 (10)	308 (5)	343 (2)	410 (1)	450 (1)
7	117 (18)	180 (10)	219 (2)	264 (1)	309 (1)	363 (1)		
8	119 (34)	175 (28)	231 (16)	268 (9)	302 (2)	365 (2)	409 (2)	436 (1)
9	131 (51)	191 (43)	242 (34)	282 (17)	322 (5)	374 (3)		
10	132 (41)	193 (31)	240 (24)	292 (17)	342 (8)	356 (3)	385 (2)	
11	128 (41)	181 (34)	225 (24)	268 (8)	318 (3)			
12	121 (6)	179 (3)						
North American avg. (Coble 1975)	93	168	230	275	318	353	375	398

Table 21. Size at age of Ozark bass calculated from seasonal catch data in Buffalo River, Arkansas.

Season	Mean calculated total length (mm) at each annulus							
	I	II	III	IV	V	VI	VII	VIII
Summer 1980		90.4	117.1	148.6	178.6	209.7	228.2	256.4
Fall 1980		107.2	128.9	157.4	182.7	209.8	243.6	
Winter 1980	59.4	94.7	138.4	171.5	194.7	211.4		
Spring 1981	53.4	93.5	138.0	170.1	182.9	206.4		
Summer 1981	51.4	91.7	135.9	172.2	197.7	224.0	231.0	

Table 22. Size at age of Ozark bass as determined from fish caught during the summer of 1980, at 12 sties in Buffalo River, Arkansas. Sample size is in parentheses.

Site	Mean calculated total length (mm) at each annulus							
	I	II	III	IV	V	VI	VII	VIII
1		96.3 (35)	122.0 (33)	153.0 (24)	187.4 (9)	222.4 (4)	238.6 (1)	254.4 (1)
2		89.2 (58)	114.4 (54)	152.5 (38)	184.4 (14)	217.7 (7)		
3		88.8 (38)	118.9 (28)	151.9 (20)	182.1 (8)	209.7 (3)		
4		89.9 (49)	119.0 (44)	153.3 (37)	189.8 (16)	215.4 (3)		
5		91.6 (106)	120.9 (101)	154.3 (66)	185.3 (30)	213.4 (8)		
6		89.5 (200)	111.0 (186)	142.1 (114)	171.6 (66)	210.9 (24)	246.8 (1)	258.4 (1)
7		89.3 (26)	120.0 (21)	152.5 (17)	192.4 (7)	220.7 (2)		
8		89.0 (105)	115.2 (82)	143.3 (66)	174.3 (33)	205.4 (4)	195.8 (1)	
9		91.0 (59)	116.3 (55)	146.4 (50)	177.2 (29)	195.8 (8)	229.2 (2)	
10		91.6 (44)	124.5 (37)	153.4 (28)	175.6 (15)	198.9 (2)		
11		92.4 (82)	124.0 (64)	151.1 (59)	179.0 (25)	201.9 (7)		
12		81.4 (5)						

Table 23. Size at age of Ozark bass as determined from fish caught during the summer of 1981, at 12 sites in Buffalo River, Arkansas. Sample size is in parentheses.

Site	Mean calculated total length (mm) at each annulus						
	I	II	III	IV	V	VI	VII
1	43.1 (28)	84.7 (25)	123.7 (21)	154.9 (14)	184.4 (10)	208.5 (2)	
2	50.1 (57)	89.0 (51)	134.2 (40)	171.1 (33)	196.5 (10)	219.4 (3)	
3	50.3 (9)	88.4 (9)	119.0 (7)	152.3 (2)	202.2 (1)		
4	50.2 (16)	88.6 (14)	137.8 (10)	173.0 (5)			
5	50.0 (60)	92.4 (48)	146.2 (21)	185.7 (14)	208.3 (3)	237.1 (2)	231.0 (1)
6	51.2 (68)	86.3 (61)	140.4 (27)	186.3 (23)	218.1 (4)	232.9 (1)	
7	50.0 (51)	93.0 (42)	138.3 (20)	176.9 (13)	206.8 (7)		
8	49.6 (63)	90.0 (59)	132.5 (25)	166.0 (15)	198.2 (7)	225.1 (1)	
9	53.4 (49)	95.2 (48)	132.9 (24)	157.5 (15)	197.4 (3)		
10	53.7 (25)	102.3 (24)	147.9 (12)	191.8 (7)	213.0 (2)	231.8 (1)	
11	53.9 (110)	95.4 (83)	137.7 (32)	167.9 (19)	185.0 (6)		
12	-						

at this site grew faster than at all other sites, but they had the slowest growth in 1981. Actually, growth remained constant at site 1 and increased at all other sites.

Food Habits and Availability

Food Habits

Until they reached a size of up to 300 mm TL smallmouth bass fed primarily on fish. At larger sizes they fed primarily on crayfish (Table 24). Smallmouth bass between 101 mm and 200 mm contained fish in 72.1% of all stomachs; insects were the second most common item (27.9%), and crayfish were third. For fish between 201 mm and 300 mm TL, fish was the most common food item but crayfish had replaced insects as the second-most common food item. For fish over 300 mm TL, insects were not found in any stomachs and crayfish replaced fish as the most common food item.

Similar trends occurred in the food habits of Ozark bass (Table 24). Ozark bass from 51 mm to 100 mm TL fed most commonly on insects (48.7% of all stomachs), then crayfish (35.9%). For fish between 101 mm and 150 mm, crayfish replaced insects as the most common diet item but both fish and insects were present in about equal proportions. Crayfish dominated the diet (85% of all stomachs) in Ozark bass larger than 150 mm TL.

Fishes identified from smallmouth bass stomachs belonged to five genera: *Etheostoma*, *Lepomis*, *Notropis*, *Campostoma*, and *Cottus*. The predominant aquatic insects in the diet of smallmouth bass were mayflies (Ephemeroptera). Ozark bass fed primarily on *Notropis* but two *Etheostoma spectabile* were found in the stomachs. Ozark bass fed more

Table 24. Stomach contents (summer 1981) of smallmouth bass and Ozark bass captured by electroshocking from 11 sites in Buffalo River, Arkansas.

	Smallmouth bass (total length)			
	< 100 mm	101-200 mm	201-300 mm	301 mm
Number sampled	50	102	87	28
Empty stomachs	10 (20.0%)	34 (33.3%)	25 (28.7%)	10 (35.7%)
Crayfish	2 (5.0%)	9 (13.2%)	31 (50.0%)	13 (72.2%)
Fish	6 (15.0%)	49 (72.1%)	40 (64.5%)	6 (33.3%)
Insects	3 (7.5%)	19 (27.9%)	6 (9.8%)	0 -
Unknown	31 (77.5%)	3 (4.4%)	1 (1.6%)	0 -

	Ozark bass (total length)		
	51-100 mm	101-150 mm	151+ mm
Number sampled	125	250	391
Empty stomachs	86 (68.8%)	109 (43.6%)	131 (33.5%)
Crayfish	14 (35.9%)	88 (62.4%)	220 (84.6%)
Fish	7 (17.9%)	27 (19.1%)	31 (11.9%)
Insects	19 (48.7%)	29 (20.6%)	21 (8.1%)
Unknown	1 (2.3%)	6 (4.3%)	2 (0.8%)

on insects than did smallmouth bass and also took a wider variety of prey. Mayflies were the most common aquatic insect taken but plecoptera, tricoptera, diptera, coleoptera, and odonata also were present. Nine of the 21 insects found in the stomachs of Ozark bass greater than 151 mm TL were dobsonfly larvae (Megaloptera).

Food Availability

Site 10 had the highest density of forage fish with 197.7 fish/10 seine hauls (Table 25) whereas site 2 had the lowest with only 51.1 fish/10 seine hauls. Crayfish densities were highest at site 12 (Table 25). However, site 2 had the highest density of any of the river sites ($8.0/m^2$). The lowest crayfish densities were found on the river at site 9 ($0.3/m^2$) and site 10 ($0.7/m^2$).

This study did not include sampling of the aquatic invertebrate populations at each site. However, Geltz and Kenny (1982) sampled aquatic invertebrates at these sites the following year and generally found a similar trend in relative density of aquatic invertebrates between sites as I found with relative density of forage fish (Figure 4).

Reproduction

The number of smallmouth and Ozark bass fry per ten seine hauls was used as an estimator of reproduction occurring at each site. In 1980, site 10 had the highest density of smallmouth bass fry with 14 fry/10 seine hauls (Table 26). In 1981, site 6 had the highest number with 19 fry/10 seine hauls and site 10 had one of the lowest with only 1 fry/10 seine hauls. In 1981, site 6 also produced the most Ozark bass

Table 25. Relative density of forage fish (August-September 1981), and crayfish (September) at 12 study sites in Buffalo River, Arkansas, during 1981.

Site no.	Forage fish		Crayfish
	No. of species	N/10 seine hauls	N/m^2
1	14	114.5	4.3
2	10	51.1	8.0
3	18	103.3	5.2
4	15	145.2	1.6
5	19	61.8	4.5
6	24	162.7	3.7
7	15	119.3	0.9
8	14	93.5	1.7
9	15	78.2	0.3
10	17	197.7	0.7
11	18	169.9	1.6
12	12	82.9	15.4
$\overline{X}$	15.9	117.6	4.0

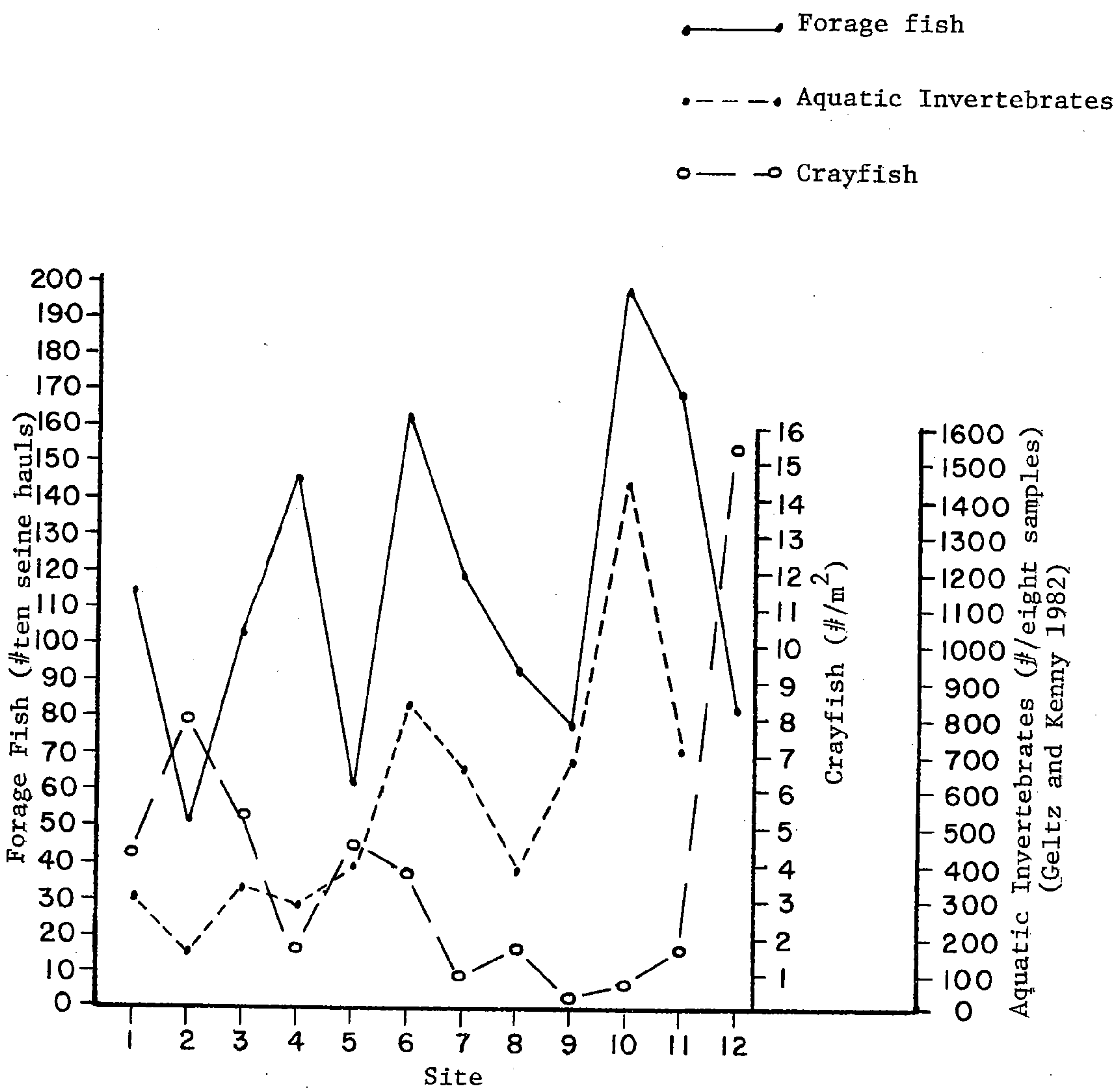

Figure 4. Relative density of forage fish, crayfish and aquatic invertebrate populations at 12 sites on the Buffalo River, Arkansas.

Table 26. Density of smallmouth bass and Ozark bass fry at 12 sites within Buffalo River, Arkansas.

	Density (N/10 seine hauls)		
	Smallmouth bass		Ozark bass
Site no.	1980	1981	1981*
1	-	0.0	2.0
2	0.0	0.0	2.0
3	0.4	6.0	0.0
4	2.7	3.0	0.0
5	1.5	8.0	3.0
6	1.0	19.0	47.0
7	0.5	0.0	0.0
8	-	0.0	0.0
9	0.0	7.0	0.0
10	14.0	1.0	1.0
11	5.0	1.0	1.0
12	0.0	1.0	1.0

* No Ozark bass fry were captured in 1980.

fry with 47 fry/10 seine hauls. No other site produced even a tenth as many as site 6.

In addition to using seine hauls, relative density of young-of-the-year captured while electroshocking was also used as an index of reproduction (Table 27). Site 10, which produced the highest number of smallmouth bass fry from seining produced the lowest number ofyoung of the year bass from electroshocking. Site 2, at which seining produced no young-of-the-year smallmouth bass, produced the most young-of-the-year during electroshocking.

Creel Census

Fisherman Profile

Extrapolation of data obtained from three sources: 1) the creel census conducted as part of this study, 2) Ditton's (1979) interviews with canoeists along the river which indicated that only 13.5% of all canoes contained fishing gear, and 3) ranger patrols that showed that 43% of all fishermen were canoeists, indicates that approximately 32,300 fishermen utilized the river in both 1980 and 1981. This estimate may only be a minimum since few early morning or late evening fishermen were included in the estimate and because bank fishermen are easily missed and therefore probably understimated.

Fifty-one percent of the fishermen encountered were local, either from one of the counties that border the river or from one of the adjacent counties. Seventy-four percent were from Arkansas. Eighty-eight percent of the fishermen encountered were male.

Forty-one percent of those censused were fishing from canoes, 45% from johnboats, and 14% from the river bank. However, heavier johnboat

Table 27. Relative density of smallmouth bass and Ozark bass less than 80 mm and 50 mm total length, respectively, captured by summer electrofishing.

	Density (no./ha)			
	Smallmouth bass		Ozark bass	
Site no.	1980	1981	1980	1981
1	3.7	0.0	0.0	0.6
2	14.0	2.4	0.0	0.0
3	4.2	0.3	0.0	0.0
4	3.5	0.7	0.0	0.0
5	5.4	0.9	0.0	0.5
6	3.7	0.6	0.4	0.4
7	1.1	2.2	0.0	0.2
8	1.7	0.0	0.0	0.0
9	1.8	0.0	0.0	0.0
10	0.7	0.5	0.0	0.0
11	1.2	0.5	0.0	0.1
12	0.0	0.0	0.0	0.0

use occurred on the lower river where waters were more suitable for motor use; 57% of all lower river fishermen encountered were in johnboats compared to 38% in the middle river and 11% on the upper river. By contrast, canoe fishermen are more common on the upper stretches with percentages decreasing in a downstream direction (78%, 56%, and 26%, respectively). Twenty-nine percent of all fishermen used live bait.

Creel Results

Fishermen on the Buffalo River had an overall catch rate of 0.47 fish/hr and a catch rate of 0.29 and 0.07 fish/hr for smallmouth bass and Ozark bass, respectively (Table 28). Harvested smallmouth bass ranged in length from 146 mm to 515 mm with a mean length of 279.6 mm. Thirty-four percent (Figure 5) of the smallmouth bass caught were smaller than the 254 mm TL length limit imposed by the Arkansas Game and Fish Commission in 1983. Fifty-two percent and 76% of the catch were smaller than 279 mm and 305 mm, respectively.

Ozark bass did not begin to show up in the creel until age III and did not begin to comprise a large portion of the total catch until age V (Figure 6). Mean length for Ozark bass in the creel was 205.7 mm with total lengths ranging from 130 mm to 255 mm.

Length Frequency

Smallmouth Bass

During the summer of 1980, 36.7% of all smallmouth bass measured (Tables 29-30) were larger than 231 mm. During the second summer this percentage dropped to 28.4%. During fall, winter and spring the

Table 28. Angler harvest (from creel census) on the Buffalo River, Arkansas, during 1980 and 1981.

Stream section	Catch rate (fish/hour)		
	All species*	Smallmouth bass	Ozark bass
Entire river	0.47	0.29	0.07
Upper river	0.56	0.15	0.04
Middle river	0.21	0.16	0.05
Lower river	0.52	0.34	0.08

* Includes smallmouth bass, Ozark bass, largemouth bass, spotted bass, channel catfish, bluegill, longear sunfish, green sunfish and rainbow trout.

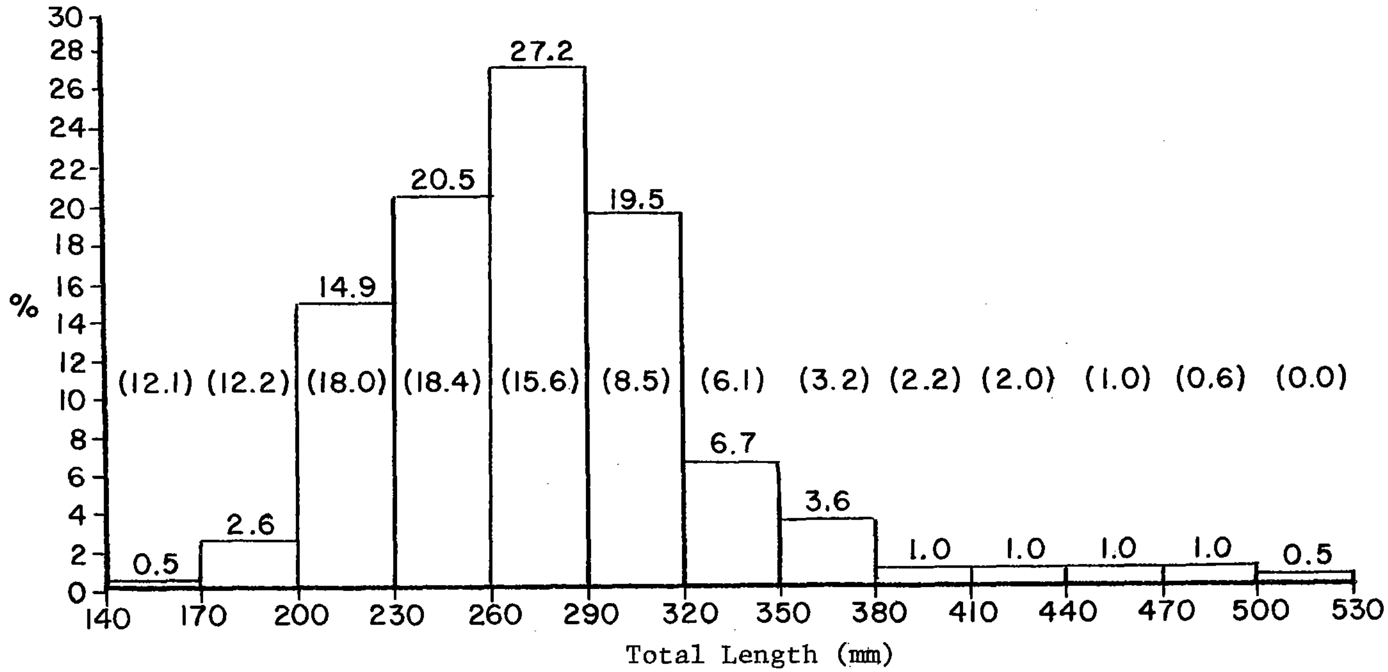

Figure 5. Length frequency distribution of the smallmouth bass caught by fishermen from Buffalo River, Arkansas. Data based on creel census results collected in 1980 and 1981. The percentage that each size class was represented in the natural population is given in parentheses.

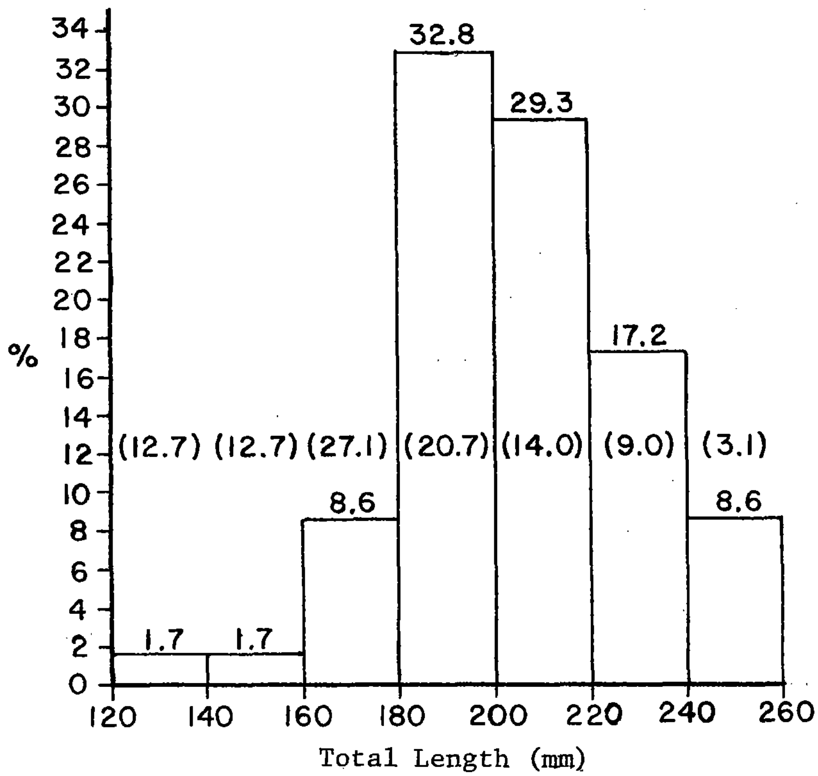

Figure 6. Length frequency distribution of the Ozark bass caught by fishermen from Buffalo River, Arkansas. Data based on creel census results collected in 1980 and 1981. The percentage that each size class was represented in the natural population is given in parentheses.

Table 29. Cumulative length frequency distribution of smallmouth bass and Ozark bass populations in Buffalo River, Arkansas.

Length (mm)	Summer 1980		Fall 1980		Winter 1980		Spring 1981		Summer 1981	
	N	%	N	%	N	%	N	%	N	%
					Smallmouth bass					
< 80	124	15.6	18	3.3	20	4.5	19	5.1	42	15.3
81-130	144	18.1	205	37.7	169	38.4	168	45.2	40	14.5
131-180	102	12.8	113	20.8	96	21.8	64	17.2	56	20.4
181-230	133	16.8	87	16.0	61	13.9	50	13.4	59	21.5
231-280	150	18.9	64	11.8	33	7.5	31	8.3	39	14.2
281-330	72	9.1	37	6.8	31	7.0	12	3.2	22	8.0
331-380	41	5.2	17	3.1	15	3.4	15	4.0	8	2.9
381+	28	3.5	3	0.6	15	3.4	13	3.5	9	3.3
	794	100.0	544	100.1	440	99.9	372	99.9	275	100.1

Table 29. Continued.

Length (mm)	Summer 1980		Fall 1980		Winter 1980		Spring 1981		Summer 1981	
	N	%	N	%	N	%	N	%	N	%
					Ozark bass					
21-50	2	0.2	3	1.0	1	1.0	9	3.0	7	0.9
51-80	92	8.2	9	3.1	39	11.4	29	9.6	57	7.2
81-110	88	7.8	53	18.3	105	30.8	57	18.9	128	16.2
111-140	158	14.0	24	8.3	30	8.8	22	7.3	166	21.0
141-170	223	19.8	50	17.3	33	9.7	38	12.6	98	12.4
171-200	324	28.8	89	30.8	75	22.0	76	25.2	158	20.0
201-230	183	16.3	43	14.9	46	13.5	50	16.6	131	16.6
231-260	50	4.4	17	5.9	11	3.2	20	6.6	40	5.1
261+	6	0.5	1	0.3	1	0.3	0	0.0	6	0.8
	1126	100.0	289	99.9	341	100.0	301	99.8	791	100.2

Table 30. Seasonal length frequency distribution for smallmouth bass for 12 sites on the Buffalo River, Arkansas. Percent occurrence is provided in parentheses.

Season & site	Total length (mm)							
	< 80	81-130	131-180	181-230	231-280	281-330	331-380	381+
Summer 1980								
1	6	13	17	9	23	6	0	3
	(7.8)	(16.9)	(22.1)	(11.6)	(29.9)	(7.8)	(0.0)	(3.9)
2	12	18	20	27	16	1	1	7
	(11.8)	(17.6)	(19.6)	(26.5)	(15.7)	(1.0)	(1.0)	(6.9)
3	12	2	1	16	14	4	2	2
	(22.6)	(3.8)	(1.9)	(30.2)	(26.4)	(7.6)	(3.8)	(3.8)
4	10	12	9	15	11	4	5	2
	(14.7)	(17.7)	(13.2)	(22.0)	(16.2)	(5.9)	(7.4)	(2.9)
5	10	8	6	1	7	6	2	0
	(25.0)	(20.0)	(15.0)	(2.5)	(17.5)	(15.0)	(5.0)	(0.0)
6	18	17	11	14	19	13	7	3
	(17.6)	(16.7)	(10.8)	(13.7)	(18.7)	(12.7)	(6.9)	(2.9)
7	4	9	1	7	2	0	1	0
	(16.7)	(37.5)	(4.2)	(29.2)	(8.3)	(0.0)	(4.2)	(0.0)
8	10	15	10	10	4	12	2	3
	(15.2)	(22.7)	(15.2)	(15.2)	(6.0)	(18.2)	(3.1)	(4.5)

Table 30. Continued.

Season & site	Total length (mm) < 80	81-130	131-180	181-230	231-280	281-330	331-380	381+
Summer 1980 (continued)								
9	13	13	9	12	23	14	12	3
	(13.1)	(13.1)	(9.1)	(12.1)	(23.2)	(14.1)	(12.1)	(3.0)
10	8	14	8	9	11	5	6	5
	(12.1)	(21.2)	(12.1)	(13.6)	(16.7)	(7.5)	(9.1)	(7.5)
11	21	22	7	12	18	7	3	0
	(23.3)	(24.5)	(7.8)	(13.3)	(20.0)	(7.8)	(3.3)	(0.0)
12	0	1	3	1	2	0	0	0
	(0.0)	(14.3)	(42.8)	(14.3)	(28.6)	(0.0)	(0.0)	(0.0)
Fall 1980								
1	0	6	8	3	4	2	1	0
	(0.0)	(25.0)	(33.3)	(12.5)	(16.7)	(8.3)	(4.2)	(0.0)
2	2	6	15	2	5	1	0	0
	(6.5)	(19.3)	(48.4)	(6.4)	(16.2)	(3.2)	(0.0)	(0.0)
3	2	11	10	4	2	3	1	0
	(6.1)	(33.3)	(30.3)	(12.1)	(6.0)	(9.2)	(3.0)	(0.0)
4	2	6	6	1	1	0	3	0
	(10.5)	(31.6)	(31.6)	(5.2)	(5.2)	(0.0)	(15.8)	(0.0)

Table 30. Continued.

Season & site	Total length (mm) < 80	81-130	131-180	181-230	231-280	281-330	331-380	381+
Fall 1980 (continued)								
5	2 (14.3)	1 (7.1)	5 (35.7)	5 (35.7)	1 (7.1)	0 (0.0)	0 (0.0)	0 (0.0)
6	8 (26.7)	8 (26.7)	5 (16.7)	3 (10.0)	2 (6.7)	3 (10.0)	1 (3.3)	0 (0.0)
7	0 (0.0)	57 (60.0)	15 (16.0)	15 (16.0)	4 (4.2)	3 (3.2)	0 (0.0)	0 (0.0)
8	0 (0.0)	34 (64.2)	10 (18.8)	6 (11.3)	1 (1.9)	1 (1.9)	1 (1.9)	0 (0.0)
9	1 (0.8)	14 (10.8)	17 (13.2)	32 (24.8)	32 (24.8)	21 (16.3)	9 (7.0)	3 (2.3)
11	1 (0.9)	62 (52.9)	22 (18.9)	16 (13.6)	12 (10.6)	3 (2.5)	1 (0.9)	0 (0.0)
Winter 1980								
1	0 (0.0)	14 (50.0)	10 (35.7)	0 (0.0)	1 (3.6)	2 (7.1)	0 (0.0)	1 (3.6)
2	5 (27.8)	8 (44.4)	5 (27.8)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Table 30. Continued.

Season & site	Total length (mm) < 80	81-130	131-180	181-230	231-280	281-330	331-380	381+
Winter 1980 (continued)								
3	0 (0.0)	0 (0.0)	8 (32.0)	5 (20.0)	5 (20.0)	7 (28.0)	0 (0.0)	0 (0.0)
4	4 (15.4)	11 (42.3)	5 (19.2)	1 (3.8)	3 (11.5)	1 (3.8)	1 (3.8)	0 (0.0)
5	0 (0.0)	3 (42.9)	4 (57.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
6	8 (8.9)	12 (13.3)	25 (27.8)	27 (30.0)	7 (7.8)	7 (7.8)	4 (4.4)	0 (0.0)
7	2 (2.7)	45 (61.7)	10 (13.7)	11 (15.1)	5 (6.8)	0 (0.0)	0 (0.0)	0 (0.0)
8	0 (0.0)	16 (69.6)	4 (17.4)	0 (0.0)	0 (0.0)	1 (4.3)	0 (0.0)	2 (8.7)
9	1 (1.1)	26 (29.9)	11 (12.7)	13 (14.9)	10 (11.5)	8 (9.2)	8 (9.2)	10 (11.5)
10	0 (0.0)	7 (38.9)	3 (16.7)	1 (5.6)	0 (0.0)	3 (16.7)	2 (11.1)	2 (11.1)

Table 30. Continued.

Season & site	Total length (mm) < 80	81-130	131-180	181-230	231-280	281-330	331-380	381+
Winter 1980 (continued)								
11	0 (0.0)	27 (71.1)	9 (23.6)	0 (0.0)	1 (2.6)	1 (2.6)	0 (0.0)	0 (0.0)
12	0 (0.0)	0 (0.0)	2 (28.6)	3 (42.8)	1 (14.3)	1 (14.3)	0 (0.0)	0 (0.0)
Spring 1981								
1	0 (0.0)	6 (40.0)	5 (33.3)	1 (6.7)	2 (13.3)	1 (6.7)	0 (0.0)	0 (0.0)
2	0 (0.0)	1 (11.1)	0 (0.0)	1 (11.1)	5 (55.6)	0 (0.0)	1 (11.1)	1 (11.1)
3	0 (0.0)	1 (16.7)	1 (16.7)	1 (16.7)	0 (0.0)	2 (33.3)	0 (0.0)	1 (16.7)
4	1 (5.6)	3 (16.6)	1 (5.6)	4 (22.2)	2 (11.1)	1 (5.6)	5 (27.7)	1 (5.6)
5	0 (0.0)	1 (33.3)	1 (33.3)	0 (0.0)	0 (0.0)	1 (33.3)	0 (0.0)	0 (0.0)
6	11 (35.5)	7 (22.6)	8 (25.8)	5 (16.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Table 30. Continued.

Season & site	Total length (mm) < 80	81-130	131-180	181-230	231-280	281-330	331-380	381+
Spring 1981 (continued)								
7	3 (6.7)	29 (64.4)	9 (20.0)	2 (4.5)	1 (2.2)	0 (0.0)	0 (0.0)	1 (2.2)
8	1 (3.6)	17 (60.7)	5 (17.8)	2 (7.2)	1 (3.6)	1 (3.6)	1 (3.6)	0 (0.0)
9	0 (0.0)	23 (21.9)	20 (19.1)	28 (26.6)	15 (14.3)	3 (2.9)	8 (7.6)	8 (7.6)
10	0 (0.0)	11 (78.6)	1 (7.1)	0 (0.0)	2 (14.3)	0 (0.0)	0 (0.0)	0 (0.0)
11	3 (3.1)	69 (71.1)	13 (13.4)	5 (5.2)	3 (3.1)	3 (3.1)	0 (0.0)	1 (1.0)
12	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Summer 1981								
1	0 (0.0)	4 (13.8)	3 (10.3)	6 (20.7)	6 (20.7)	6 (20.7)	3 (10.4)	1 (3.4)
2	2 (3.4)	8 (13.8)	12 (20.7)	16 (27.6)	10 (17.3)	8 (13.8)	1 (1.7)	1 (1.7)

Table 30. Continued.

Season & site	Total length (mm) < 80	81-130	131-180	181-230	231-280	281-330	331-380	381+
Summer 1981 (continued)								
3	1 (12.5)	2 (25.0)	4 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (12.5)	0 (0.0)
4	2 (9.1)	3 (13.6)	5 (22.8)	1 (4.5)	3 (13.6)	1 (4.5)	2 (9.1)	5 (22.8)
5	2 (25.0)	1 (12.5)	0 (0.0)	3 (37.5)	1 (12.5)	1 (12.5)	0 (0.0)	0 (0.0)
6	3 (23.1)	5 (38.4)	1 (7.7)	1 (7.7)	2 (15.4)	1 (7.7)	0 (0.0)	0 (0.0)
7	16 (45.7)	2 (5.7)	4 (11.5)	4 (11.5)	8 (22.8)	1 (2.9)	0 (0.0)	0 (0.0)
8	0 (0.0)	4 (22.2)	5 (27.8)	5 (27.8)	3 (16.6)	1 (5.6)	0 (0.0)	0 (0.0)
9	0 (0.0)	0 (0.0)	4 (40.0)	2 (20.0)	0 (0.0)	3 (30.0)	0 (0.0)	1 (10.0)
10	6 (35.3)	1 (5.9)	6 (35.3)	4 (23.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Table 30. Continued.

Season & site	< 80	81-130	131-180	181-230	231-280	281-330	331-380	381+
	Total length (mm)							
Summer 1981 (continued)								
11	10 (18.9)	10 (18.9)	12 (22.7)	17 (32.1)	2 (3.7)	0 (0.0)	1 (1.9)	1 (1.9)
12	0 (0.0)	0 (0.0)	0 (0.0)	4 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

percentage of bass over 230 mm was 22.3, 21.3, and 19.0%, respectively.

Ozark Bass

During the summer of 1980, 50% (Table 29, Table 31) of all Ozark bass captured were larger than 171 mm. During the fall, the percentage of catchable Ozark bass increased slightly to 51.9% of the population; however, it declined to a low of 39.0% during the winter. In spring, the percentage of larger Ozark bass was 48.8% but this percentage again declined to 42.5% during the summer of 1981.

Mortality

Smallmouth Bass

Overall annual mortality rate was 42% as calculated from a catch curve (Table 32). The upper river sites had the lowest annual mortality (39%) and the middle river had the highest (53%). The highest mortality rates occurred at sites 4 and 7.

Ozark Bass

Annual mortality rate for Ozark bass was 58% overall (Table 32). Mortality increased in the downstream direction.

Table 31. Seasonal length frequency distribution for Ozark bass from 12 sites at Buffalo River, Arkansas. Percentage of occurrence is provided in parentheses.

Season & site	Total length (mm) < 50	51-80	81-110	111-140	141-170	171-200	201-230	231-260	261+
Summer 1980									
1	0 (0.0)	2 (4.5)	4 (9.1)	4 (9.1)	12 (27.3)	12 (27.3)	5 (11.3)	3 (6.9)	2 (4.5)
2	0 (0.0)	7 (9.6)	10 (13.7)	8 (10.9)	13 (17.9)	21 (28.7)	6 (8.2)	8 (11.0)	0 (0.0)
3	0 (0.0)	8 (18.2)	3 (6.8)	6 (13.6)	7 (15.9)	12 (27.3)	5 (11.4)	3 (6.8)	0 (0.0)
4	0 (0.0)	5 (8.1)	2 (3.2)	10 (16.1)	12 (19.4)	14 (22.6)	14 (22.6)	5 (8.1)	0 (0.0)
5	0 (0.0)	8 (5.4)	8 (5.4)	18 (12.1)	36 (24.2)	41 (27.5)	26 (17.4)	11 (7.4)	1 (0.7)
6	2 (0.7)	25 (8.4)	10 (3.4)	63 (21.3)	45 (15.2)	86 (29.0)	54 (18.3)	8 (2.7)	3 (1.0)
7	0 (0.0)	5 (16.7)	0 (0.0)	3 (10.0)	9 (30.0)	7 (23.3)	5 (16.7)	1 (3.3)	0 (0.0)
8	0 (0.0)	20 (13.9)	13 (9.0)	6 (11.1)	33 (22.9)	43 (29.9)	17 (11.8)	2 (1.4)	0 (0.0)

Table 31. Continued.

Season & site	Total length (mm) < 50	51-80	81-110	111-140	141-170	171-200	201-230	231-260	261+
Summer 1980 (continued)									
9	0 (0.0)	3 (3.0)	6 (6.1)	12 (12.1)	13 (13.1)	41 (41.3)	20 (20.4)	4 (4.0)	0 (0.0)
10	0 (0.0)	2 (3.3)	10 (16.4)	6 (9.8)	10 (16.4)	19 (31.1)	12 (19.7)	2 (3.3)	0 (0.0)
11	0 (0.0)	6 (5.0)	18 (15.2)	12 (10.1)	33 (27.7)	28 (23.5)	19 (16.0)	3 (2.5)	0 (0.0)
12	0 (0.0)	1 (20.0)	4 (80.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Fall 1980									
1	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (50.0)	2 (50.0)	0 (0.0)	0 (0.0)
2	3 (15.0)	4 (20.0)	7 (35.0)	0 (0.0)	2 (10.0)	2 (10.0)	1 (5.0)	1 (5.0)	0 (0.0)
3	0 (0.0)	0 (0.0)	3 (13.6)	1 (4.5)	6 (27.3)	6 (27.3)	1 (4.5)	5 (22.7)	0 (0.0)
4	0 (0.0)	0 (0.0)	4 (44.4)	1 (11.1)	0 (0.0)	3 (33.3)	1 (11.1)	0 (0.0)	0 (0.0)

Table 31. Continued.

Season & site	Total length (mm) < 50	51-80	81-110	111-140	141-170	171-200	201-230	231-260	261+
Fall 1980 (continued)									
5	0	0	4	0	8	4	1	1	0
	(0.0)	(0.0)	(22.2)	(0.0)	(44.5)	(22.2)	(5.6)	(5.6)	(0.0)
6	0	5	11	6	8	19	17	2	0
	(0.0)	(7.4)	(16.1)	(8.9)	(11.7)	(28.0)	(25.0)	(2.9)	(0.0)
7	0	0	1	5	12	20	6	1	0
	(0.0)	(0.0)	(2.2)	(11.1)	(26.7)	(44.4)	(13.4)	(2.2)	(0.0)
8	0	0	13	6	7	9	3	3	0
	(0.0)	(0.0)	(31.7)	(14.6)	(17.1)	(22.0)	(7.3)	(7.3)	(0.0)
9	0	0	0	1	3	11	8	3	0
	(0.0)	(0.0)	(0.0)	(3.8)	(11.6)	(42.3)	(30.8)	(11.6)	(0.0)
11	0	0	10	4	4	13	3	1	1
	(0.0)	(0.0)	(27.8)	(11.1)	(11.1)	(36.1)	(8.3)	(2.8)	(2.8)
Winter 1980									
1	0	0	0	0	1	11	6	2	0
	(0.0)	(0.0)	(0.0)	(0.0)	(5.0)	(55.0)	(30.0)	(10.0)	(0.0)
2	1	5	12	5	0	2	0	0	0
	(4.0)	(20.0)	(48.0)	(20.0)	(0.0)	(8.0)	(0.0)	(0.0)	(0.0)

Table 31. Continued.

Season & site	< 50	51-80	81-110	111-140	141-170	171-200	201-230	231-260	261+
	Total length (mm)								
Winter 1980 (continued)									
3	0 (0.0)	2 (14.3)	5 (35.7)	3 (21.4)	1 (7.1)	1 (7.1)	2 (14.3)	0 (0.0)	0 (0.0)
4	0 (0.0)	0 (0.0)	9 (50.0)	5 (27.8)	1 (5.6)	3 (16.7)	0 (0.0)	0 (0.0)	0 (0.0)
5	0 (0.0)	0 (0.0)	3 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
6	0 (0.0)	27 (25.5)	18 (17.0)	8 (7.5)	12 (11.3)	20 (18.9)	17 (16.0)	3 (2.9)	1 (0.9)
7	0 (0.0)	1 (3.7)	14 (51.9)	4 (14.8)	6 (22.2)	0 (0.0)	1 (3.7)	1 (3.7)	0 (0.0)
8	0 (0.0)	0 (0.0)	23 (74.2)	2 (6.4)	2 (6.4)	4 (12.9)	0 (0.0)	0 (0.0)	0 (0.0)
9	0 (0.0)	3 (4.1)	15 (20.2)	3 (4.1)	7 (9.4)	25 (33.8)	16 (21.6)	5 (6.8)	0 (0.0)
10	0 (0.0)	0 (0.0)	1 (12.5)	0 (0.0)	0 (0.0)	4 (50.0)	3 (37.5)	0 (0.0)	0 (0.0)

Table 31. Continued.

Season & site	Total length (mm) < 50	51-80	81-110	111-140	141-170	171-200	201-230	231-260	261+
Winter 1980 (continued)									
11	0 (0.0)	0 (0.0)	5 (41.7)	0 (0.0)	1 (8.3)	5 (41.7)	1 (8.3)	0 (0.0)	0 (0.0)
12	0 (0.0)	1 (33.3)	0 (0.0)	0 (0.0)	2 (66.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Spring 1981									
1	0 (0.0)	0 (0.0)	1 (2.3)	1 (2.3)	10 (23.2)	17 (39.5)	12 (27.9)	2 (4.7)	0 (0.0)
2	2 (15.4)	2 (15.4)	2 (15.4)	0 (0.0)	0 (0.0)	5 (38.4)	0 (0.0)	2 (15.4)	0 (0.0)
3	0 (0.0)	1 (16.7)	0 (0.0)	0 (0.0)	1 (16.7)	2 (33.3)	1 (16.7)	1 (16.7)	0 (0.0)
4	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (100.0)	0 (0.0)	0 (0.0)
5	1 (5.3)	0 (0.0)	1 (5.3)	1 (5.3)	6 (31.6)	5 (26.3)	5 (26.3)	0 (0.0)	0 (0.0)
6	3 (5.6)	18 (33.3)	10 (18.5)	5 (9.3)	4 (7.4)	4 (7.4)	7 (12.9)	3 (5.6)	0 (0.0)

Table 31. Continued.

Season & site	Total length (mm) < 50	51-80	81-110	111-140	141-170	171-200	201-230	231-260	261+
Spring 1981 (continued)									
7	0 (0.0)	1 (2.4)	5 (12.2)	5 (12.2)	4 (9.8)	16 (39.0)	7 (17.1)	3 (7.3)	0 (0.0)
8	1 (3.2)	0 (0.0)	16 (51.6)	2 (6.5)	5 (16.1)	5 (16.1)	1 (3.2)	1 (3.2)	0 (0.0)
9	0 (0.0)	1 (3.6)	6 (21.4)	2 (7.1)	4 (14.3)	10 (35.7)	3 (10.8)	2 (7.1)	0 (0.0)
10	0 (0.0)	1 (3.2)	2 (6.5)	4 (12.9)	2 (6.5)	8 (25.8)	10 (32.3)	4 (12.9)	0 (0.0)
11	1 (3.8)	0 (0.0)	14 (53.9)	2 (7.7)	2 (7.7)	4 (15.4)	1 (3.8)	2 (7.7)	0 (0.0)
12	1 (14.3)	5 (71.4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (14.3)	0 (0.0)
Summer 1981									
1	1 (2.6)	2 (5.3)	1 (2.6)	4 (10.6)	7 (18.4)	12 (31.6)	10 (26.3)	1 (2.6)	0 (0.0)
2	0 (0.0)	6 (8.1)	8 (10.8)	8 (10.8)	6 (8.1)	19 (25.7)	16 (21.6)	10 (13.5)	1 (1.4)

Table 31. Continued.

Season & site	Total length (mm) < 50	51-80	81-110	111-140	141-170	171-200	201-230	231-260	261+
Summer 1981 (continued)									
3	0 (0.0)	0 (0.0)	2 (18.2)	1 (9.1)	3 (27.2)	3 (27.2)	2 (18.2)	0 (0.0)	0 (0.0)
4	0 (0.0)	2 (10.5)	4 (21.1)	1 (5.3)	1 (5.3)	5 (26.3)	5 (26.3)	0 (0.0)	1 (5.3)
5	1 (1.4)	11 (15.3)	7 (9.7)	16 (22.2)	9 (12.5)	11 (15.3)	13 (18.0)	2 (2.8)	2 (2.8)
6	2 (1.5)	14 (10.3)	38 (27.9)	26 (19.1)	7 (5.2)	12 (8.8)	27 (19.8)	9 (6.7)	1 (0.7)
7	1 (1.3)	7 (9.1)	7 (9.1)	18 (23.4)	7 (9.0)	19 (24.7)	14 (18.2)	4 (5.2)	0 (0.0)
8	0 (0.0)	3 (3.0)	12 (12.0)	29 (29.0)	13 (13.0)	21 (21.0)	17 (17.0)	4 (4.0)	1 (1.0)
9	0 (0.0)	2 (2.2)	17 (18.7)	19 (20.9)	15 (16.4)	27 (29.7)	9 (9.9)	2 (2.2)	0 (0.0)
10	0 (0.0)	0 (0.0)	3 (7.3)	5 (12.2)	14 (34.2)	9 (21.9)	7 (17.1)	3 (7.3)	0 (0.0)

Table 31. Continued.

Season & site	Total length (mm) < 50	51-80	81-110	111-140	141-170	171-200	201-230	231-260	261+
Summer 1981 (continued)									
11	2 (1.5)	10 (7.6)	29 (22.0)	39 (29.5)	16 (12.1)	20 (15.2)	11 (8.3)	5 (3.8)	0 (0.0)
12	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Table 32. Instantaneous mortality rates, Z, annual survival rate, S, and annual mortality rates, A. Computed by the catch curve method from electroshocking data for smallmouth bass and Ozark bass in various river sections and sites on Buffalo River, Arkansas.

River location	Smallmouth bass			Ozark bass*		
	Z	S	A	Z	S	A
Overall	0.55	0.58	0.42	0.87	0.42	0.58
Upper river	0.49	0.61	0.39	0.60	0.55	0.45
Middle river	0.76	0.47	0.53	0.90	0.41	0.59
Lower river	0.52	0.59	0.41	1.14	0.32	0.68
Site 1	0.51	0.60	0.40	0.74	0.48	0.52
Site 2	0.63	0.53	0.47	0.39	0.68	0.32
Site 3	0.54	0.58	0.42	0.67	0.51	0.49
Site 4	1.55	0.21	0.79	0.88	0.41	0.59
Site 5	0.49	0.61	0.39	0.74	0.48	0.52
Site 6	0.63	0.53	0.47	0.84	0.43	0.57
Site 7	1.64	0.19	0.81	1.28	0.28	0.72
Site 8	0.60	0.55	0.45	0.98	0.38	0.62
Site 9	0.42	0.66	0.34	1.07	0.34	0.66
Site 10	0.42	0.66	0.34	1.15	0.32	0.68
Site 11	0.64	0.53	0.47	1.11	0.33	0.67

* Based on ages 5-8.

CHAPTER V

DISCUSSION

Population Levels

Smallmouth Bass

Several possible factors operating singly or in combination could explain the within-site summertime variations that occurred in the smallmouth bass populations. Some of these factors are as follows:

1. Smallmouth bass had home ranges that encompassed a greater area than my sample area; these fish may not have been present in the sample area on all sampling dates.
2. Smallmouth bass avoided electric shock or sound waves produced by the boat motor and generator after once being captured.
3. Mortality occurred over the summer due to a) angling pressure, b) natural causes, or c) the effects of electroshocking and/or handling during sampling.
4. Fish grew to a size where they became more visible and more susceptible to capture as the summer progressed.
5. Fish left the area either during or subsequent to electroshocking.

The work of previous authors (Larimore 1952; Gerking 1953; Fajen 1962; Munther 1970) have established that most smallmouth bass do have defined home ranges but Fajen (1962) and Munther (1970) have also demonstrated that a segment of the bass population moves freely between two or more pools. For example, 24% of the bass marked by Munther were recovered outside the pool in which they were tagged. Similiarly, Fajen found that 34% of the bass tagged in the stable pools of Little Saline Creek and 46% of the bass tagged in Big Buffalo Creek, Missouri, had left the pool in which they were initially marked. Fajen hypothesized that home range was usually restricted to one pool but that some home ranges consisted of several pools as much as a half mile apart. Even during droughts, Fajen found that flow was sufficient to allow bass movement across riffles.

Some of the fluctuations observed in summer populations in this study probably were at least partially related to differences in home range size among different subsections of the smallmouth bass population. Higher water levels in 1981 would have facilitated interpool movement and may explain the greater variability in 1981 data as compared to that in the 1980 data. Movement across riffles to other portions of a home range violates one assumption of equal catchability in the depletion estimate and may be responsible for the wide confidence intervals associated with some population estimates.

Smallmouth bass also appeared to detect the electric field and/or vibrations generated by the sampling boat and were observed to move in front of and away from the boat. However, it is unlikely that this avoidance behavior was a major cause of the fluctuations in serial population estimates. This conclusion was reached because during both summers the final population estimate at 8 of 12 sites were equal to or higher than the first population estimate (Table 3).

Mortality either from angling, sampling stress, or natural causes could have also played an important part in determining population levels. However, if mortality was the factor, the population estimates would be expected to decline with each subsequent sample. Instead, a steadily declining population occurred only at sites 5 and 12 in 1980 and at sites 2, 3, and 4 in 1981. In addition, the most accessible sites (1, 2, 7, and 8) and the ones receiving the most canoe use and which might be expected to have the highest mortality due to fishing pressure, primarily sites 2, 9, 10, and 11 (Table 2), were not the ones with the greatest seasonal decline in populations.

A final factor that could have affected population estimates was increased susceptibility to capture of young smallmouth bass as the summer progressed. As the season progressed, smaller bass grew enough to become more visible to the sampling crew and were more easily captured. In addition, electrofishing was more selective for larger bass (Reynolds and Simpson 1978). Therefore, it would be reasonable to assume that a greater proportion of small bass were missed in sampling early in the season than were missed later in the season. This effect appeared to be occurring in my samples. In summer 1980 at 10 of 12 sites and in 1981 at 6 of 12 sites the percentage of smallmouth bass less than or equal to 150 mm total length in the sample was higher in the last sampling period than in the first (Table 33). In summary, movement into and out of the study pools and growth of small bass appeared to be the major factors responsible for summertime variability of population estimates.

Smallmouth bass showed an overall decline from summer 1980 to 1981. It appears reasonable that mortality or movement of bass, both in response to drought conditions, are the main causative agents.

Table 33. Frequency of capture of smallmouth bass larger and smaller than 150 mm total length for each summer sample period. Results are listed in chronological order for each site.

Site number	1980 <150 mm	1980 >150 mm	1980 % ≤150 mm	1981 <150 mm	1981 >150 mm	1981 % ≤150 mm
1 (a)	1	20	4.8	1	7	12.5
(b)	11	20	35.5	5	8	38.5
(c)	11	14	44.0	0	8	0.0
2 (a)	10	19	34.5	6	15	28.6
(b)	18	24	42.9	5	15	25.0
(c)	16	15	51.6	8	9	47.1
3 (a)	1	5	16.7	-	-	-
(b)	11	17	39.3	2	3	40.0
(c)	2	17	5.3	3	0	100.0
4 (a)	7	9	43.8	2	6	25.0
(b)	4	17	19.0	5	5	50.0
(c)	16	10	61.5	2	0	100.0
5 (a)	-	-	-	0	0	-
(b)	12	10	54.5	0	1	0.0
(c)	7	2	77.8	3	4	42.9
6 (a)	9	17	34.6	1	2	33.3
(b)	10	26	27.8	2	1	66.7
(c)	21	19	52.5	5	2	71.4
7 (a)	7	5	58.3	4	1	80.0
(b)	6	6	50.0	9	11	45.0
(c)	-	-	-	7	1	87.5
8 (a)	0	8	0.0	3	1	75.0
(b)	13	19	40.6	0	5	0.0
(c)	17	9	65.5	3	2	60.0
9 (a)	8	26	22.2	0	1	0.0
(b)	-	-	-	1	8	11.1
(c)	15	28	34.9	0	0	-
10 (a)	1	13	7.1	1	1	50.0
(b)	7	18	28.0	5	6	45.5
(c)	17	10	63.0	2	2	50.0

Table 33. Continued.

Site number	1980			1981		
	<150 mm	>150 mm	% ≤150 mm	<150 mm	>150 mm	% ≤150 mm
11 (a)	-	-	-	8	9	47.1
(b)	15	26	36.6	2	4	33.3
(c)	30	8	78.9	17	13	56.7
12 (a)	1	3	25.0	0	1	0.0
(b)	1	2	33.3	0	3	0.0
(c)	-	-	-	-	-	-

Mean weight for smallmouth bass captured during the fall was significantly lower than those captured in summer (Appendix D, Table 53). Such differences could result from either mortality of older bass or from movement of younger bass out of the tributaries into the main river. I saw little evidence of extensive summer-fall mortality of older fish. I conclude that a fall influx was responsible for the observed changes in those seasons. Movement of fish appeared to continue over the winter with some sites (2, 5, and 11) being abandoned by all but the smallest bass (Appendix D, Table 54).

Spring population declines again appeared to reflect bass movements, but this time the movement was into the tributaries. This hypothesis is strengthened because only site 11 had a spring population size that was greater than those that were present in winter.

There was considerable evidence for over winter mortality. The mean weight of smallmouth bass in summer 1981 was lower than in summer 1980 but did not differ significantly from that in spring 1981. For this relationship to have occurred in conjunction with a greatly reduced summer 1981 population suggested that mortality among the older, larger bass in the population had occurred over winter and spring.

Ozark Bass

Variations in summer Ozark bass populations probably were due to the same factors that affected smallmouth bass: movement in or out of the site and home ranges that included more than one pool. It is doubtful that gear selectivity was as great a factor for Ozark bass as for smallmouth bass, although it obviously played a factor in the accuracy of the overall estimates. The reason for this conclusion is that very few young of the year and age I Ozark bass were ever captured so the possibility was reduced that the faster growing segment of the population became more visible in late summer.

There also did not appear to be a migration of Ozark bass out of the tributaries during fall as was seen with smallmouth bass. Such a movement may occur later in winter since the decrease in mean weight at that time (Appendix D, Table 55) suggests a winter influx of smaller fish into the population. Some sites (5 and 12) were all but deserted in winter by Ozark bass while others (sites 6 and 9) had their highest populations in that time of year. It is possible that the reduction in mean weight that occurred in winter was due in part to some portions of the Ozark bass population becoming torpid and unresponsive to sampling. Several very large Ozark bass at site 7 were observed slowly moving up out of the layer of leaves covering the bottom of the pool in response to the electroshock but were too deep to be netted. It is also probable that winter mortality was responsible for some of the reductions taht occurred in population size (Table 4) and mean weights for each site; however, the near desertion of some sites and the large increases in the populations of others supports the hypothesis of mass winter movement of Ozark bass out of tributaries and some river sites in response to some environmental variable. Spring and warmer temperatures appeared to result in increased movement of Ozark bass; mean weights increased, populations at sites 6 and 9 declined, and other populations increased. Ozark bass populations declined from the first to the second summer but not as markedly as did the smallmouth bass. The explanation for these changes appeared to be the same for both species.

Density

Population estimates, densities, mean weights, and standing crops for various species are frequently used to compare the population being studied with previously studied populations. However, as Paragamian and Cobble (1975) pointed out, these comparisons are difficult to make even though the reported densities and standing crops are accurate. They attributed this difficulty to the facts that 1) estimates are based on different size ranges, 2) estimates are based not on size of stock at carrying capacity, but carrying capacity minus harvest, and 3) estimates often are based on total area in the study site instead of on area of useable habitat. Similar conclusions were reached by Hunt (1971) for brook trout (Salvelinus fontinalis).

Work has been done on the relationship between habitat and density or standing crop. For example, the density of drift feeding salmonids is thought to be controlled by a space-food and sometimes a space shelter mechanism (Chapman 1966). In this model, territory size was reduced as velocity increased because less space was need to obtain food. There was, however, a minimum space requirement at periods of low flow or high densities. The space-shelter relationship hypothesis also allows for shelter from predators and from high flood flows or prey abundance (Slaney and Northcote 1974) to regulate density.

Several factors in the space-shelter relationship are known to affect smallmouth bass density. Trautman (1942) in Ohio and Bulkley et al. (1976) in Iowa, found a significant correlation between stream gradient and distribution of smallmouth bass. Paragamian (1981) found that smallmouth bass densities and standing crops were positively associated with the proportion of gravel and cobble substrates. Orth

(1980), however, found no significant correlation between biomass/total area or biomass/weighted useable area in Glover Creek, Oklahoma, and felt that useable habitat generally was not limiting abundance in this system. However, Orth did observe that biomass/total area was near zero at sites where weighted useable area was less than 5% of total surface area and concluded that useable area limited abundance of adult smallmouth bass under marginal (summer) habitat conditions.

Limited work has also been done on the relationship between rock bass standing crop and density and habitat. Previous studies have indicated that rock bass are found in streams of medium size (Funk 1975) and are associated with gravel substrates (Trautman 1957; Brown 1960; Jones 1973), cobble (Jones 1970; Jones 1973), boulder (Gerking 1945; Trautman 1957; Jones 1970), bedrock (Trautman 1957; Jones 1970; Jones 1973), and vegetation (Gerking 1945; Trautman 1957; Brown 1960). None of these studies have dealt specifically with *A. constellatus*.

Smallmouth Bass

The increase in density from summer 1980 to fall can be explained by movement of bass out of the tributaries and the 64.6% decrease in density from summer 1980 to summer 1981 can be explained by mortality associated with drought. The range of densities encountered during this study, 1.0 to 143.7 bass/ha, were consistent with ranges that have been reported in Missouri (Fajen 1972) for Huzzah Creek (58 bass/ha) and Courtois Creek (56 bass/ha) and by Brown (1960) for several streams in Ohio (16, 26, 29, and 87 bass/ha, respectively). The range of seasonal mean densities (11.8 to 46.8 bass/ha) was lower than the 118 and 132 bass/ha that Paragamian (1973) found in either the Plover River or the

Red Cedar River in Wisconsin, and were much lower than the densities (11 to 1,772 bass/ha) reported for the Maquoketa River, Iowa (Paragamian 1981). Overall, the Buffalo River did not appear to be as productive as some other smallmouth bass streams.

Seasonal density was found to be closely related to depth and substrate but less closely to velocity (Table 34, Appendix H). Greater amounts of silt and aquatic vegetation were correlated with reduced density during summer. Conversely larger amounts of boulder and cobble-boulder substrates (in 1980 but not in 1981) were correlated with higher summer densities. The importance of cobble-boulder as a factor in 1980 but its reduced importance in 1981 suggests that cobble-boulder possibly was acting as a limiting factor at the higher density present in summer 1980, but was not at the lower levels of 1981. The amount of cobble alone was not found to be correlated with density and the absence in importance of cobble-boulder in the correlations at low densities suggests that cobble was not a preferred substrate. If such an interpretation is correct, the 1980 population of smallmouth bass had reached a level where marginal or less preferred habitat was being occupied.

During summer, smallmouth bass density was positively correlated with the maximum depth of the site and the area of the site with a depth less than 0.26 m. Bass density was negatively correlated with the area of the site with a depth between 0.76 and 1.25 meters. Deep water is important for shelter from high summer temperatures and during periods of reduced flow and the depth range of zero to 0.25 m is the depth range that defines the amount of riffles where feeding most often occurs. In this study the correlation between density and this shallow depth zone

Table 34. Correlations between habitat parameters and density of smallmouth bass in Buffalo River, Arkansas.

Season	Habitat parameter	r
Summer 1980	Area of site (ha)	-0.67
Summer 1981	Area of site (ha)	-0.79
Summer 1980	Percent of site with depth of 0.76-1.25 m	-0.65
Summer 1981	Percent of site with depth of 0.76-1.25 m	-0.64
Summer 1980	Percent of site with a silt substrate	-0.70
Summer 1981	Percent of site with a silt substrate	-0.73
Summer 1981	Percent of site covered by aquatic vegetation	-0.65
Summer 1980	Gradient (m/km)	0.66
Summer 1981	Gradient (m/km)	0.87
Summer 1980	Maximum depth of pool (m)	0.58
Summer 1981	Maximum depth of pool (m)	0.67
Summer 1980	Percent of site with a depth < 0.26 m	0.69
Summer 1981	Percent of site with a depth < 0.26 m	0.64
Summer 1980	Percent of site with boulder substrate	0.61
Summer 1981	Percent of site with boulder substrate	0.58
Summer 1980	Percent of site with a cobble-boulder substrate	0.60
Fall	Maximum depth of pool (m)	0.93
Winter	Percent of site with a depth of 0.26-0.75 m	-0.61
Spring	Maximum depth of pool (m)	0.69

Significant at 0.05.

was linear which suggests that the optimum ratio of riffle to pool was not present even at site 2 which has approximately 45.5% of the site with depth less than 0.26 m.

Stream gradient was positively correlated and size of the site was negatively correlated with smallmouth bass density in summer. Both factors are interrelated since the size of pools and riffles increases and gradient decreases as one moves downstream.

The only other correlations that occurred during other seasons were a positive correlation during fall and spring between density and maximum depth and a negative correlation during winter between density and the percent of a site with a depth range of 0.26 and 0.75 m. It is apparent that physical habitat most closely limited the population during low summer flows. Superficially, the absence of correlation between density and other physical habitat factors may appear surprising. However, Paragamian (1981) found that density was correlated only with the amount of course gravel and cobble gravel substrate in the Maquoketa River. One might suspect that if habitat was generally a limiting factor for smallmouth bass then streams with higher smallmouth bass densities like the Maquoketa River would have more correlations between density and habitat factors than would the Buffalo River. However, one must remember that a single factor operating at a single instant in time can effectively limit a population. The data indicate that the Buffalo River is not an optimum habitat for smallmouth bass. In such habitats, it is also possible that habitat does not directly limit populations but operates through factors such as food. In such cases, an increase in silt substrate, for example, might have more of an impact on the Buffalo River than would similar increases in more fertile waters like the Maquoketa River.

Ozark Bass

The 40.7% reduction in mean density of Ozark bass in summer 1981 compared to that in summer 1980 was correlated with the severe drought. The drought apparently had less of an effect on Ozark bass than on smallmouth bass. Unlike what was found with smallmouth bass, the mean density of Ozark bass during the fall did not increase over what it was in the previous summer and Ozark bass did not migrate out of the tributaries until winter.

No correlation was found between canoe density and Ozark bass density at any season. It appears that increasing use of the Buffalo River by recreational canoeists was not affecting the Ozark bass population. However, correlations were found between other habitat factors and Ozark bass density (Table 35, Appendix I). The number of habitat parameters that were significantly correlated with density during summer 1980 was twice the number in summer 1981. It is also significant that twice as many habitat parameters were correlated with density of smallmouth bass in summer 1980 than for Ozark bass and four times as many in summer 1981 (Table 36). This analysis would seem to indicate that smallmouth bass in the Buffalo River were more limited by habitat than were Ozark bass. Three of the four parameters correlated with Ozark bass density in summer 1980 (depth less than 0.26 m, boulder substrate and the depth range of 0.76 to 1.25 m) were also correlated with smallmouth bass density. However, unlike smallmouth bass, densities of Ozark bass were not negatively correlated with amounts of silt substrate. Ozark bass density was, however, negatively correlated

Table 35. Correlations between habitat parameters and density of Ozark bass in Buffalo River, Arkansas.

Season	Habitat parameter	r
Summer 1980	Percent of site with depth of 0.76-1.25 m	-0.71
Summer 1981	Percent of site with depth of 0.76-1.25 m	-0.64
Summer 1980	Percent of site with bedrock substrate	-0.62
Summer 1980	Percent of site with a depth < 0.26 m	0.75
Summer 1981	Percent of site with a depth < 0.26 m	0.65
Summer 1980	Percent of site with boulder substrate	0.58
Fall	Percent of site with a current velocity of 11-20 cm/s	-0.69
Fall	Percent of site with a depth 0.76-1.25 m	-0.78
Fall	Percent of site with depth < 0.26 m	0.71
Winter	None	
Spring	Area of site (ha)	-0.61
Spring	Percent of site with depth of 0.76-1.25 m	-0.64
Spring	Gradient (m/km)	0.78

Significant at 0.05.

Table 36. Correlations between habitat parameters and density of smallmouth bass and Ozark bass.

Season	Smallmouth bass	Correlation	Ozark bass
Summer 1980	Depth < 0.26 m	Positive	Depth < 0.26 m
	Boulder substrate	Positive	Boulder substrate
	Cobble-boulder substrate	Positive	
	Maximum depth (m)	Positive	
	Gradient (m/km)	Positive	
	Depth of 0.76-1.25 m	Negative	Depth of 0.76-1.25 m
	Silt substrate	Negative	Bedrock substrate
	Area (m^2)	Negative	
Fall 1980	Maximum depth (m)	Positive	Depth < 0.26 m
		Negative	Velocity of 11-20 cm/s
		Negative	Depth of 0.76-1.25 m
Winter 1980	Depth of 0.26-0.75 m	Negative	
Spring 1981	Maximum depth (m)	Positive	Gradient (m/km)
		Negative	Area (ha)
		Negative	Depth of 0.76-1.25 m
Summer 1981	Depth < 0.26 m	Positive	Depth < 0.26 m
	Maximum depth (m)	Positive	
	Gradient (m/km)	Positive	
	Boulder substrate	Positive	
	Depth of 0.76-1.25 m	Negative	Depth of 0.76-1.25 m
	Silt substrate	Negative	
	Aquatic vegetation	Negative	
	Area (ha)	Negative	

with the amount of bedrock. Areas of bedrock on the Buffalo River are often associated with faster flow. Fast current is not suited for Ozark bass because their body shape requires them to expend a great amount of energy in these habitats to maintain themselves in a current and to capture prey. During the second summer, only depth was correlated with density. Since the amount of area less than 0.26 m was again significant, it could indicate that the prime foraging areas (riffles) were still critical and that food may have been a limiting factor for Ozark bass populations, even at the reduced density level of 1981.

During the fall, depth (less than 0.26 m) was again positively correlated with density; higher velocities (11-20 cm/s) and the depth range of 0.76-1.25 m were negatively correlated with density. The effect of higher velocities would be explained by the body-shape hypothesis presented above. The positive effect of shallow depths would again be associated with foraging needs.

Stream gradient was the only habitat factor positively correlated with density in spring as the fish began their upstream movements. Area was negatively correlated in spring. As with smallmouth bass, the positive relationship between density and area is probably not one of cause and effect but exists because of the interrelationship betwen gradient and size of pools that occurs on most rivers, where area of the pool increases as gradient decreases. The amount of area in the depth range 0.76 m to 1.25 m was also negatively correlated with density in spring as it was during both summers and fall for Ozark bass and during the summers for smallmouth bass. The reason for the negative correlation between the amount of the site in this depth range is unclear.

Densities of smallmouth bass and Ozark bass showed colinear relationships during both summers:

$$R = 11.99 + 0.77\ S \quad r = 0.78 \quad (1980)$$

$$R = 10.40 + 1.00\ S \quad r = 0.80 \quad (1981)$$

where R = Ozark bass density and S = smallmouth bass density and during winter:

$$\ln R = 0.97 + 0.05\ S \quad r = 0.91.$$

Apparently site conditions during summer that favored one species also favored the other. Furthermore, it appears that competition is not severe between the two species. This relationship between these two species differs from that found by Surber and Seaman (1949) in West Virginia streams and Sanderson (1958) in the Potomac River tributaries where increased density of rock bass and yellowbelly sunfish was negatively correlated with density, growth and condition factors of smallmouth bass.

The correlation of fish density with habitat factors even at low density levels indicated that habitat played an important part in determining smallmouth bass and Ozark bass population sizes. In such situations, the stocking of additional bass as has been proposed would not be beneficial and could be detrimental.

Standing Crop

Smallmouth Bass

The fluctuation in standing crops within sites between seasons reflects the seasonal movements of the population discussed under density. Standing crops in the Buffalo River ranged from 0.05 to 23.17 kg/ha with means ranging from a low of 1.89 kg/ha in summer 1981 to a high of 5.73 kg/ha in summer 1980. Although these values are low, they are comparable to other values reported in the literature. Brown (1960) found similar results in Ohio where he reported standing crops ranging from 3.3 kg/ha in the North Fork of the Little Miami River to 13.5 kg/ha in Massie Creek. Fajen (1972) also found similar results in Missouri where the 11-year mean was 8.6 kg/ha for Courtois Creek and the 7-year mean was 9.0 kg/ha for Huzzah Creek. The values I found were much lower than those reported by Paragamian (1981) on the Maquoketa River, Iowa where biomass was as high as 182.0 kg/ha at one site. In fact, of the 11 sites that he sampled in 1978, only four had standing crops lower than the standing crops obtained on the Buffalo River.

Canoe activity was not correlated with standing crops except during the spring when there was a positive correlation between standing crop and total number of canoes ($r = 0.71$). This relationship was best described by: $SC = -0.16 + 0.002X$, where SC = standing crop in kg/ha and X = the number of canoes floating past the site during spring. One possible explanation of this relationship is that increased canoe traffic benefitted smallmouth bass populations on the upper river by dirctly interfering with the harvest of bass or by discouraging serious fishermen from fishing during this time of year.

Standing crop was also correlated with various seasonal habitat parameters (Table 37, Appendix J). Substrate appeared to be a limiting factor for smallmouth bass during summer and somewhat during spring. This relationship was most dramatic during the summer of 1980 when standing crops were high. During this period increased silt and decreased amounts of bedrock were associated with decreased standing crop. This relationship did not occur in 1981. A similar relationship

Table 37. Correlations between habitat parameters and standing crop of smallmouth bass in Buffalo River, Arkansas.

Season	Habitat parameter	r
Summer 1980	Area of site (ha)	-0.59
Summer 1981	Area of site (ha)	-0.62
Summer 1980	Percent of site with silt substrate	-0.66
Summer 1980	Percent of site with a depth of 0.76-1.25 m	-0.62
Summer 1981	Gradient (m/km)	0.79
Summer 1981	Maximum depth (m)	0.60
Summer 1980	Percent of site with bedrock substrate	0.62
Summer 1980	Percent of site with depth < 0.26	0.68
Fall	Gradient (m/km)	0.94
Fall	Maximum depth of pool (m)	0.76
Winter	Percent of site with velocity > 20 cm/s	0.60
Spring	Percent of site with silt and sand substrate	-0.65

Significant at 0.05.

was seen in spring when increased amounts of silt and sand again corresponded with decreased levels of standing crop. Substrate did not appear to be important as a limiting factor during other seasons.

Velocity did not appear to limit standing crop except in winter when the amount of water of high velocity (21+ cm/s) appeared to be positively correlated with standing crop. It is possible that mixing associated with high velocity could be important in preventing ice formation and in keeping water temperature uniform and possibly warmer.

Depth was found to also be an important factor affecting standing crop at the higher 1980 population levels. In particular, the percentage of a site with a depth less than 0.26 m was positively correlated with standing crop. As stated earlier, this shallow water area may be important as a foraging area. Conversely, the area of a site having a depth between 0.76 and 1.25 m was negatively correlated with standing crop. The importance of this depth range and the way this interaction operates is unclear. Maximum depth was also important to standing crop in 1981. This habitat was probably important as a source of refuge from high summer temperature.

Gradient (postively) and area of the pool (negatively) also were correlated with standing crop. These factors are interrelated because smaller pools are usually located upriver (i.e., higher gradients). These upstream sites tended to be more silt free and had proportionally more of the preferred habitat identified earlier under density. The relationship between gradient and standing crop during fall seems to support the downstream movement of bass out of the headwaters and tributaries hypothesis presented earlier.

The correlation between various substrate factors and standing crop during summer 1980 and the absence of these correlations in 1981 suggested that the 1980 summer standing crop levels were near or approaching carrying capacity of the stream but had been reduced below carrying capacity by summer 1981. If this hypothesis is true, then smallmouth bass populations in the Buffalo River are limited by the low flows that occur cyclically in this region.

The correlation found by Paragamian (1981) between course gravel and cobble-gravel substrates and standing crop were not found in the Buffalo River. The Maquoketa river is a stream that contains large quantities of silt and fine gravel and limited amounts of the types of substrate that I found to be optimal for smallmouth bass on Buffalo River (Appendix B). It may be that in streams like the Maquoketa River where suitable substrate is not prevalent that changes in standing crop are closely correlated with changes in the amounts of preferred substrate. However, in streams like the Buffalo River, where preferred substrate is abundant, standing crops may be correlated with such things as food availability. Such a relationship is suggested by the fact that increases in the amount of silt and sand were correlated with decreases in standing crop. The question then arises as to why a stream like the Buffalo River where suitable habitat is abundant does not produce as much bass biomass as the Maquoketa River which is limited in the amount of "preferred" habitat? The difference may be explained as a result of regional differences in overall productivity.

Ozark Bass

The lower standing crops in summer 1981 than in summer 1980 were probably drought related. However, the changes were much less pronounced on Ozark bass than they were on smallmouth bass. Levels of canoe activity in a site was not correlated with Ozark bass standing crop. There were correlations (Table 38), however, between summer and spring standing crops and habitat parameters present at the site (Appendix K).

Depth appeared to be the most important summer habitat factor particularly during the summer of 1981. However in spring, substrate was the most important factor. In contrast with smallmouth bass, silt did not correlate with the standing crop of Ozark bass.

There were few similiarities between habitat preferences between the two species (Table 39). This lack of similarity suggests that some partitioning of habitat is occurring and that habitat may be limited during periods when populations are large or during periods such as drought.

Habitat Utilization

Depth

There was no difference in the summertime depth utilization patterns of these two species (Table 7); however, there was a statistical difference in winter. In winter, smallmouth bass were netted in water as deep as 2.13 m whereas Ozark bass were taken at a maximum depth of only 1.63 m. In spite of these differences, mean depths for both species were almost identical. However, Ozark bass tended to occupy a wider range of depths in winter than did smallmouth bass. The sample size for Ozark bass was too small during other seasons to allow a valid comparison of depth utilization between these two species.

Table 38. Correlation between habitat parameters and standing crop of Ozark bass in Buffalo River, Arkansas.

Season	Habitat parameter	r
Summer 1980	Percent of site with depth of 0.76-1.25 m	-0.61
Summer 1981	Percent of site with depth of 0.76-1.25 m	-0.66
Summer 1981	Percent of site with depth > 1.75 m	-0.81
Summer 1980	Percent of site with velocity of 11-20 cm/s	-0.58
Summer 1980	Percent of site with depth < 0.26 m	0.66
Summer 1981	Percent of site with depth < 0.26 m	0.67
Summer 1981	Maximum depth (m)	0.58
Fall	None	
Winter	None	
Spring	Area of site (ha)	-0.64
Spring	Gradient (m/km)	0.77
Spring	Percent of site with cobble and boulder substrate	0.63
Spring	Percent of site with cobble substrate	0.61

Significant at 0.05.

Table 39. Correlations between habitat parameters and standing crop of smallmouth bass and Ozark bass.

Season	Smallmouth bass	Correlation	Ozark bass
Summer 1980	Depth < 0.26 m	Positive	Depth < 0.26 m
	Bedrock substrate	Positive	
	Depth of 0.76-1.25 m	Negative	Depth of 0.76-1.25 m
	Area (m^2)	Negative	Velocity of 11-20 cm/s
	Silt substrate	Negative	
Fall 1980	Gradient (m/km)	Positive	
	Maximum depth (m)	Positive	
Winter 1980	Velocity > 20 cm/s	Positive	
Spring 1981	Silt-sand substrate	Negative	Area (ha)
		Positive	Gradient (m/km)
		Positive	Cobble-boulder substrate
		Positive	Cobble substrate
Summer 1981	Area (ha)	Negative	Depth of 0.76-1.25 m
		Negative	Depth > 1.75 m
	Maximum depth (m)	Positive	Maximum depth (m)
	Gradient (m/km)	Positive	Depth < 0.26 m

Velocity

The difference in the velocities utilized by smallmouth bass between the two summers could result in two ways from higher water levels in summer 1981 than in summer 1980.

1. If smallmouth bass selected locations in the current as a function of substrate and not velocity or depth, the data would show a decided difference in velocities utilized.

2. If drought-induced mortality rates were higher among smallmouth bass that occupied the pools than among those residing in the current, the data would show a difference in the velocities utilized. The first of these explanations appears the most likely.

There did not appear to be any winter habitat partitioning along the velocity axis among these two species (Table 10). However, there was a significant difference in velocity utilization during summer. During summer 1981, Ozark bass utilized areas of the river with less current than those occupied by smallmouth bass. This preference by Ozark bass for slower velocities than those utilized by smallmouth bass may have been due to the morphological differences between the two species. Compared with smallmouth bass, Ozark bass have shorter, thicker bodies that require more expenditure of energy to maintain position against the current than smallmouth bass with their more streamlined body. Morphology could also explain why Ozark bass prefer water with less current during the winter when they become less active than during the summer. Reduced food competition between these two species in the winter may eliminate the need for selecting different areas of the stream.

Substrate

In winter, the two species utilized the same substrates, both species being found primarily over bedrock and secondarily over boulder (Table 14). Winter is a period of limited activity, thus competition-related partitioning of habitat might not be important.

During the summer of 1981, the substrate utilized by Ozark bass shifted to boulder and secondarily to bedrock whereas smallmouth bass utilized cobble as well as boulder and bedrock. In the previous summer, smallmouth bass also utilized boulder-bedrock substrates. However, habitat utilization between these two species still differed significantly because of the secondary preference of Ozark bass for vegetation and of smallmouth bass for cobble and gravel.

Coefficient of Condition

Smallmouth Bass

There was a seasonal cycle in the coefficient of condition of the smallmouth bass population. However, the two summer populations also differed, probably because of the effects of the 1980 drought. The seasonal range of values of 1.13 to 1.45 that were obtained on the Buffalo River are similar to those obtained for populations on other streams and rivers (Table 40). The reason for the unusually high K values at sites 7 and 10 during both summers is due probably to low population densities. In contrast, fish in site 2, which were present at high density, had a low K factor during summer and fall.

Condition factor was positively correlated in summer 1981 with total length as has been reported by Bennett (1937) and Latta (1963).

Table 40. Coefficients of condition, K, for smallmouth bass from various streams.

Locality and authority	K(TL)
Buffalo River, Arkansas (present study 1980-81)	1.13-1.45
Maquoketa River, Iowa (Paragamian 1979)	1.28-1.29
Volga River, Iowa (Paragamian 1979)	1.29
Turkey River, Iowa (Ackerman 1974)	1.27
Des Moines River, Iowa (Reynolds 1965)	1.45

The data indicate that bass in the smaller length classes, primarily one-and two-year-old fish, were more food limited than other sizes of fish. The largest number of fish also occupied this size range. This relationship did not occur during summer 1980 and its absence under early drought conditions indicate that competition for food was not critical under normal conditions and that the drought effect on the aquatic invertebrate community may not have been felt on the fishery until the second summer. This is consistent with the hypothesis that the summer, with its low flows, is the period that limits bass populations in the Buffalo River. The reduced K factors for smaller bass in 1981 but not 1980 could also be related to the increased production of young-of-the-year in 1981 (Table 26) as a result of the stable water conditions of the drought coupled with the impact of another strong year class produced in 1980. Together they produced a large population of small fish that were foraging on an already limited aquatic invertebrate community.

Ozark Bass

Condition factors of Ozark bass varied from highs in the summer to lows in winter. As reported for smallmouth bass, these variations appear to reflect changes in feeding and activity levels associated with falling temperatures. The spring K factor differed between Ozark bass and smallmouth bass since Ozark bass K in spring was significantly higher than it was in winter. This may indicate that Ozark bass gain weight faster in spring than do smallmouth bass. This accelerated weight gain could be because Ozark bass become active and start feeding earlier in the spring than smallmouth bass. As in smallmouth bass, the K factor for fish from summer 1981 did not reach the summer 1980 level. These data indicate that drought was affecting Ozark bass as well as smallmouth bass. Since A. constellatus was only identified as a separate species in 1977, no comparative information is available. However, the condition factors for Buffalo River Ozark bass, 1.74-2.16, were within the range of condition factors cited by Carlander (1977) for A. rupestris, a closely related specdies. Buffalo River Ozark bass had K values that were similar to those of rock bass in Alabama (1.64-2.28), Michigan (2.05-2.13), and Illinois (1.86-2.49) but would be rated average to poor compared to Minnasota values.

Relationship Between K and Density, Habitat and Canoe Use

There was a linear relationship ($r = 0.66$) during 1981 between K and smallmouth bass density. This relationship is described by: $K = 1.13 + 0.006\ N$; where N = smallmouth bass density in number/ha. The relationship was not present during the first summer and may indicate that those sites with higher densities during the second summer had good food availability compared to the other sites but in the beginning of the drought (summer 1980), food was not as limiting because the impacts of the drought on the aquatic invertebrate and forage fish populations had not been fully realized. No relationship was detected between density and K for Ozark bass.

The number of canoes using a stretch of river was correlated with condition coefficients for both species. A negative relationship existed during both summers for Ozark bass:

1980 $K = 3.62 - 0.17\ C$ $(r = -0.89)$

1981 $K = 3.81 - 0.22\ C$ $(r = -0.75)$

where C = the total number of canoes using that river section during the year. This negative relationship would indicate that canoe traffic was having a disruptive impact on Ozark bass foraging, food supply or on energy expenditures because of increased disturbance.

In contrast, during the summer of 1981, there was a positive correlation between smallmouth bass K and canoe levels ($r = 0.66$):

$K = 1.13 + 0.006\ C$. This positive correlation probably reflects the improvement of K with the reduction of density associated with removal of fish by anglers. Since food appears to be limiting during summer 1981, the reduction of the population by even limited angling would cause an improvement in the amount of food available for the remainder of the populations.

Most of the habitat parameters (Table 41, Appendix L) that were significantly correlated with condition factor in smallmouth bass were substrate types and correlations were in the opposite direction from what is considered good smallmouth bass habitat. The amount of silt and sand were positively correlated with K, whereas the amount of boulder, gravel, and gravel-cobble were negatively correlated with K. Coefficient of condition was positively correlated with those substrate parameters that were negatively correlated with density and standing crop. These correlations may indicate that food was the limiting factor for smallmouth bass. The same trend appears to hold for Ozark bass (Table 42, Appendix L) during the first summer when populations were high. At that time, the amount of silt and sand was positively correlated with K and the amount of boulder substrate was negatively

Table 41. Correlations between habitat parameters and coefficient of condition of smallmouth bass in Buffalo River, Arkansas.

Season	Habitat parameter	r
Summer 1980	Percent of site with depth < 0.26 m	-0.58
	Percent of site with boulder substrate	-0.64
	Mean depth (m)	0.60
	Percent of site with sand substrate	0.64
	Percent of site with silt and sand substrate	0.63
	Percent of site with depth > 1.75 m	0.59
Summer 1981	Percent of site with boulder substrate	-0.83
	Percent of site with gravel and cobble substrate	-0.74
	Percent of site with gravel substrate	-0.69
	Percent of site covered with aquatic vegetation	-0.63
	Mean depth (m)	0.73
	Percent of site with silt substrate	0.74
	Percent of site with silt and sand substrate	0.71
	Percent of site with velocity of 1-10 cm/s	0.61
Fall 1981	None	
Winter 1980	Percent of site with gravel and cobble substrate	-0.61
	Percent of site with silt and sand substrate	-0.64
	Percent of site with depth of 0.26-0.75 m	0.68
	Percent of site with bedrock substrate	0.80
	Percent of site with boulder and bedrock substrate	0.84
Spring 1981	Percent of site with pebble substrate	0.60

Significant at 0.05.

Table 42. Correlations between habitat parameters and coefficient of condition of Ozark bass in Buffalo River, Arkansas.

Season	Habitat parameter	r
Summer 1980	Percent of site with boulder substrate	-0.64
	Percent of site with sand substrate	0.82
	Percent of site with silt and sand substrate	0.62
Summer 1981	Percent of site with bedrock substrate	-0.77
	Percent of site with boulder and bedrock substrate	-0.84
	Percent of site with cobble substrate	0.75
	Percent of site with cobble and boulder substrate	0.74
	Percent of site with gravel and cobble substrate	0.62
Fall 1980	Percent of site with depth of 0.26-0.75 m	-0.65
	Percent of site with velocity of 11-20 cm/s	-0.63
	Percent of site with sand substrate	0.64
Winter 1980	Gradient (m/km)	-0.59
	Percent of site with depth of 0.26-0.75 m	0.60
	Percent of site with bedrock substrate	0.77
	Percent of site with boulder and bedrock substrate	0.81
Spring 1981	None	

Significant at 0.05.

correlated with K. However, at the reduced population levels of 1981, cobble, cobble-boulder and cobble-gravel, the more typical Ozark bass habitat factors were positively correlated with K.

During the winter months, condition factor of smallmouth bass and Ozark bass was positively correlated with the proportion of bedrock and boulder-bedrock combinations at the site and negatively correlated with the proportions of gravel-cobble and silt-sand. This relationship may be associated with the need for these species to have crevices and cracks in which to seek protection during periods of cold temperatures.

These two species differed in the correlations between condition factors and habitat parameters during summer 1981 (Table 43). The proportion of gravel-cobble was negatively correlated with K in smallmouth bass but positively correlated with that of Ozark bass. The difference between these correlations could result from partitioning of habitat during periods of stress.

Age and Growth

Smallmouth Bass

There were faster growth rates for smallmouth bass captured during summer 1980 and fall than for those captured during winter, spring and summer 1981. Movement of smallmouth bass out of the tributaries and into the river during colder weather with the tributary bass having a slower growth rate could explain these results if these tributary bass remained in the river during the spring and following summer. Such an explanation when coupled with the reduced densities and population levels that have been previously described would require high mortality among the river bass. Another possibility is that the mortality

Table 43. Correlations between habitat parameters and K factors of smallmouth bass and Ozark bass.

Season	Smallmouth bass	Correlation	Ozark bass
Summer 1980	Sand substrate	Positive	Sand substrate
	Silt-sand substrate	Positive	Silt-sand substrate
	Mean depth (m)	Positive	
	Depth > 1.75 m	Positive	
	Boulder substrate	Negative	Boulder substrate
	Depth of < 0.26 m	Negative	
Summer 1981	Silt substrate	Positive	Cobble substratee
	Silt-sand substrate	Positive	Cobble-boulder substrate
	Velocity of 1-10 cm/s	Positive	Gravel-cobble substrate
	Mean depth (m)	Positive	
	Boulder substrate	Negative	Bedrock substrate
	Gravel-cobble substrate	Negative	Boulder-bedrock substrate
	Gravel substrate	Negative	
	Aquatic vegetation	Negative	
Fall 1980		Positive	Sand substrate
		Negative	Depth of 0.26-0.75 m
		Negative	Velocity of 11-20 cm/s
Winter 1980	Depth of 0.26-0.75 m	Positive	Depth of 0.26-0.75 m
	Bedrock substrate	Positive	Bedrock substrate
	Boulder-bedrock substrate	Positive	Boulder-bedrock substrate
	Silt-sand substrate	Negative	Gradient (m/km)
	Gravel-cobble substrate	Negative	
Spring 1981	Pebble substrate	Positive	

associated with the drought was greatest among the faster growing individuals of the populations.

Excepting first year growth which appeared to be exceptional and that of the fourth year which was slightly slower than normal, the lengths attained by each age group seemed consistent with lengths attained by smallmouth bass in Ozark streams in Missouri (Table 44). However, compared to lengths reported by Reynolds (1965) and Paragamian (1973) for fish from rivers in Iowa and Wisconsin, respectively, Buffalo River smallmouth bass were smaller, especially after completion of the second and third growing seasons. Overall, however, Buffalo River smallmouth bass were very similar in size to the North American average provided by Coble (1975), exceeding it in age groups I and VI. A comparison of growth during 1975-1976 (Kilambi et al. 1977) with growth of 1980-1981 indicate that growth rates have increased over the five year period, particularly for age III+ bass and young-of-the-year; but have declined for age II bass. The increase over this period could be due to improvement of aquatic habitat as land along the river was removed from agricultural and residentual activities. The decrease in second year growth could result from increased intraspecific competition due to greater survival of age I fish.

Ozark Bass

During the process of aging Ozark bass scales, the first annulus was consistently missed for scale samples taken during summer 1980 and fall. The difficulty in locating the first annulus was not due to poor technique in aging Ozark bass scales since scales were not read until all sampling was complete and scales were organized by site not season.

Table 44. Size at age of smallmouth bass from different waters.

Locality and authority	Total length (mm) at each annulus								
	I	II	III	IV	V	VI	VII	VIII	IX
Buffalo River, AR (present study)	115	166	222	268	319	367	413	439	
Buffalo River, AR (Kilambi et al. 1977)	109	177	221	259	313	347			
Big Piney River, MO (Funk and Fleener 1974)	86	160	216	269	325	378	411	434	445
Courtois Creek, MO (Fajen 1972)	80	152	213	272	338	380	420	442	495
Huzzah Creek, MO (Fajen 1972)	81	155	218	273	331	390	438	461	484
Illinois River, OK (Leonard & Jenkins 1954)	86	173	246	328					
Little River System, OK (Finnell 1955)	99	188	241	290	338	371			
Plover River, WI (Paragamian 1973)	91	158	220	297	366	410	440	455	476
Red Cedar River, WI (Paragamian 1973)	100	190	274	329	383	407	424	444	

Table 44. Continued.

Locality and authority	I	II	III	IV	V	VI	VII	VIII	IX
	Total length (mm) at each annulus								
Potomac River, MD (Sanderson 1955)	107	188	249	295	333	386			
Des Moines River, IA (Reynolds 1965)	119	229	297	340	388	411			
North American Average (Coble 1975)	93	168	230	275	318	353	375	398	423

Therefore, the difficulty in locating this annulus for fish caught during summer 1980 and fall was repeated on 12 separate occasions. It may be that Ozark bass did not form an annulus during this period. Failure to form annulus has been documented in slow-growing bluegill populations (Regier 1959). Data from annuli II-V suggests the presence of two different subpopulations and that the slower growing subpopulation had higher drought related mortality than did the faster growing ones. This trend is the opposite of what was found for smallmouth bass.

Sites 5 and 10 that produced good growth for Ozark bass also produced good growth for smallmouth bass.

Although no growth data have been published on Ozark bass, comparisons can be made between Ozark bass and rock bass. Growth of age I Ozark bass were similar to that for smallmouth bass in that it was greater in populations in the Buffalo River than for rock bass in most other waters (Table 45). After the first year, however, growth tended to fall behind that found in other waters.

Food Habits and Availability

Food Habits

There was shift in diet composition from fish and insects to crayfish and fish as smallmouth bass increased in size; this shift would minimize interspecific competition. Ozark bass shifted away from utilization of insects and toward heavy dependence on crayfish as they grew. Such shifts reduced food overlap between Ozark bass of various sizes. The two species also appeared to have diets which would reduce interspecific competition; smallmouth bass fed on fish until they

Table 45. Size at age of Ozark bass from different waters. Growth data obtained from Carlandaer (1977). Data is for _A. rupestris_ except for the data from the present study which is for _A. constellatus_.

Locality and authority	Total length (mm) at each annulus								
	I	II	III	IV	V	VI	VII	VIII	IX
Buffalo River, AR (present study)	53	93	125	157	183	211	231	256	
Black River, MO	40	76	119	152	185	185			
Missouri statewide	41	86	140	178	203	216			
Missouri headwaters	41	81	132	175	203	218			
Missouri middle river	43	91	142	178	198	213			
Missouri lower river	46	94	145	188	208	211			
Missouri best average	53	114	175	221	239	249	262	277	279
Unweighted mean for OH, IL, IN, KY, MO	49	91	139	170	194	206	216	225	229
Unweighted mean for NC, VA, OK, TN	59	117	160	188	198	214	228	258	
Illinois River, OK	43	107	147	188	206				

reached 301 mm total length while Ozark bass fed heavily on crayfish and insects while in this size range.

These results are similar to those reported by Kilambi et al. (1977) for Buffalo River smallmouth bass in 1975. In 1975, both adult and immature smallmouth bass had a larger percentage of fish than crayfish in their diet during summer. Aggus (1973) found smallmouth bass foraged principally on fish during the summer and only relied on crayfish during the winter. Kilambi et al. (1977) reported a similar relationship with adult smallmouth bass on the Buffalo River. These data are consistent with the current data except for the fact that smallmouth bass over 300 mm fed almost exclusively on crayfish in my study. With immature bass feeding on fish year round and adults feeding on fish during most of the year, it is probable that a major perturbation such as drought would affect the minnow population which would in turn affect the smallmouth bass population more than the Ozark bass population. In addition, these impacts should be felt most by the younger, smaller bass. This hypothesis may explain the reduced smallmouth bass population during the second summer.

Food Availability

There were correlations between density and standing crop of smallmouth bass populations during the summer of 1981 and relative density of crayfish and aquatic invertebrate populations during September 1981 and 1982, respectively (Table 46). The relationship with crayfish density was positive whereas the relationship with the relative density of aquatic invertebrates was negative. No correlations were found between smallmouth bass condition factors and densities of

Table 46. Correlations between summer density (#/ha), standing crop (kg/ha), and condition factors of smallmouth bass and Ozark bass and relative densities of forage fish (#/10 seine hauls), crayfish (#/m^2) and aquatic invertebrate populations (#/8 samples) in Buffalo River, Arkansas.

Species & indices	Prey	Relationship	r
	Smallmouth bass		
Density (N)	Crayfish (C)	$\ln N = 1.01 + 0.18\ C$	0.63
Density (N)	Aquatic invertebrates (I)	$N = 151.17 - 22.71 \ln I$	-0.68
Standing crop (S)	Crayfish	$S = -0.91 + 0.93\ C$	0.70
Standing crop (S)	Aquatic invertebrates (I)	$S = 26.58 - 4.04 \ln I$	-0.76
	Ozark bass		
Density (N)	Crayfish (C)	$\ln N = 1.81 + 0.29\ C$	0.68
Density (N)	Forage fish (F)	$N = 195.66 - 37.13 \ln F$	-0.60
Standing crop (S)	Crayfish (C)	$S = -0.77 + 1.14\ C$	0.81
Standing crop (S)	Forage fish (F)	$S = 25.02 - 4.85 \ln F$	-0.62
Standing Crop (S)	Aquatic invertebrates (I)	$S = 22.78 - 3.28 \ln I$	-0.62
Condition factor (K)	Aquatic invertebrates (I)	$K = -187.58 + 0.45\ I$	0.80

Data on aquatic invertebrate densities from Geltz and Kenny (1982) crayfish.

Correlations similar to those found with smallmouth bass were also found for Ozark bass (Table 46). Ozark bass density and standing crop were positively correlated with density of crayfish populations and negatively correlated with forage fish density. Although density of Ozark bass was not correlated with relative density of aquatic invertebrate populations, standing crop was found to be negatively correlated. Also, the only correlation between Ozark bass condition factor and density of food organisms was a positive correlation between condition factor and relative density of aquatic invertebrates.

These correlations between density, standing crop and K and the local availability of the three major food items suggests that food is a limiting factor in this Ozark stream. However, the relationship between predator and prey is not clear; the positive correlation between numbers of crayfish and density of both species could be due to parallel correlations between both fish and crayfish but could also mean that crayfish are a major food item and were an important determinant of standing crop and density. If the latter relationship exists, the positive correlation would suggest that the existing densities of both species were not high enough to impact the crayfish population. A correlation was found between 1981 crayfish density and standing crop for smallmouth bass and gradient, however, no correlation was found for standing crop of Ozark bass. Standing crop for smallmouth bass, but not Ozark bass, was also correlated with gradient during summer 1981; this suggests that crayfish populations may be influenced by similar habitat factors as smallmouth bass and may explain the heavier use of crayfish as a food item during this study than was found in 1975 by Kilambi et al. (1977). In 1975, a period of peak flow (Appendix A), the population of forage fish probably was higher, permitting a greater use of fish than in the low flow period encountered during this study. The inverse relationship between density and standing crop of smallmouth bass and Ozark bass and the relative densities of aquatic invertebrates and forage fish suggested that not only were aquatic invertebrates and forage fish densities important factors in regulating the populations of these two species, but also that after a summer of low flow and restricted pools, these two species were also impacting the density levels of their food items. If this interpretation is correct, stocking of additional predators could cause a reduction in density and standing crop of both smallmouth bass and Ozark bass. In addition, any factor that reduced the production of either aquatic invertebrates or the minnow population would have a direct impact on the fishery. Similarly, an improvement in minnow/aquatic invertebrate habitat or production would have a positive impact on the fishery.

Reproduction

Although both methods used to evaluate reproduction have their limitations as indicators of reproduction (the difficulty of seining in rubble substrate and the size selectivity of electroshocking), the use of electroshocking as a relative index of reproduction appeared to be the better of the two methods. Estimates for smallmouth bass reproduction were obtained for 11 of 12 sites during 1980 using electroshocking compared to 7 of 10 sites using seines. Although the results varied, both methods resulted in relative estimates of smallmouth bass reproduction for 8 of 12 sites during 1981. Neither method produced good results for Ozark bass although seining had the best potential for success due to the small size of young-of-the-year Ozark bass and the difficulty in seeing and netting them from a moving boat.

Based on the electroshocking samples, there was a decline of 79% in smallmouth bass young of year mean density from 1980 to 1981 (Table 26). This relationship corresponds with the 64.6% decrease in smallmouth bass density for the population as a whole. Site 2 had the highest production of young of the year bass of all sites for both summers. These data provide some evidence that canoeing was not disrupting spawning, since site 2 has more canoe activity during the spawning season than any other site. Site 3 also receives heavy spring canoe traffic and it too had a relatively high density of young-of-the-year during summer 1980. There was a tendency for higher young-of-the-year relative densities to occur in the upper sections of the river. The only site to have more young of the year smallmouth bass in 1981 than 1980 was site 7. Possibly the reason for this increase is that site 7 smallmouth bass had a much higher coefficient of condition in 1981 than smallmouth bass in other sites which could have resulted in increased fecundity.

Creel Census

Creel Results

Although the overall catch rates of 0.47 fish/hr is low compared to rates for other smallmouth bass streams (Table 47), the catch rate for smallmouth bass was higher than that reported for other rivers. In comparison the catch rate for Ozark bass was slightly lower than the 0.1

Table 47. Catch rates of smallmouth bass for various waters.

Streams and authority	Catch rate (fish/hour)	
	All fish	Smallmouth bass
Buffalo River, AR (present study 1981)	0.47	0.29
Courtois Creek, MO (Fajen 1972; Fleener 1975)	0.84	0.07-0.12
Huzzah Creek, MO (Fleener 1971; 1972)	0.64	0.06-0.10
Big Piney River, MO (Fleener 1974)	0.59	0.02-0.06
Current River, MO (Fleener 1971, 1973)	0.34	0.09-0.10
Potomac River, MD (Sanderson 1958, 1959)	0.87	0.06-0.13
South Branch, Potomac River, MD (Surber and Seaman 1949)		0.08
Cacapon River, WV (Surber and Seaman 1949)		0.06-0.13
Shenandoah River, VA (Surber 1969)		0.16-0.72
Red Cedar River, WI (Paragamian and Coble 1975)		0.07
Little Miami River, OH (Brown 1960)		0.04

Source: Funk (1975) and Paragamian and Coble (1975) fish/hr rate for the Little Miami River system in Ohio reported by Brown (1960). These catch rates suggest that the fishery is not being seriously depleted by current fishing pressure and that current canoe levels are not having a serious effect on overall angler success. Ozark bass do not appear to be actively sought after by anglers since the large population of Ozark bass should be represented by a higher catch rate than what was found.

Fleener (1975) in his work on the heavily exploited Courtois Creek found that 83% of the smallmouth bass caught were less than 5 years old. On the Buffalo River only 65.7% of the catch are less than age V. These data indicate that the smallmouth bass population is not being overfished. Further evidence that the Buffalo River fishery is not over exploited is provided by the fact that age I, II, and III fish comprised less than 20% of the catch, compared to 78% for the Red Cedar River, Iowa (Paragamian 1973), 62% for the Niagria River, Missouri (Funk and Fleener 1966), and 86% for the Maquoketa River, Iowa (Paragamian 1979). Another sign of lack of exploitation is that mean length for the catch from Buffalo River was 280 mm compared to 262 mm in Red Cedar River, Iowa (Paragamian 1973) and 242 and 259 mm for two sections of the Maquoketa River, Iowa (Paragamian 1979).

The percentage composition of smallmouth bass less than 230 mm total length in the creel is lower than the percentage composition of these fish in the natural population (Figure 5). The data suggest that anglers were selective in their harvest and that fishing pressure was not heavy. Smallmouth bass over 350 mm total length were represented in the creel in approximately the same percentage as they were present in the natural population. These data provide evidence that over-exploitation was not occurring but that smaller smallmouth bass were more vulnerable to angling than larger bass.

The proportion of Ozark bass less than 180 mm total length in the creel is far lower than their proportion in the natural population. These data also indicate that anglers are selecting for larger Ozark bass (Figure 6) and suggest that angling pressure on Ozark bass was low.

Since Ozark bass, like the rock bass (Carlander 1977), probably reach maturity at age II and did not appear in the creel in large numbers until age V, they have the potential for spawning at least three times before they become susceptible to angling pressure.

Length Frequency

Smallmouth Bass

The large percentage (36.7%) of bass that are primarily impacted by angling (> 231 mm) indicates that the population is not being over-harvested. Even during the fall, when nearly all of the fishing has occurred and the population of small bass had been increased by the influx of tributary bass and young-of-the-year, the portion of the population larger than 230 mm was still 22.2%.

There was a lower percentage of bass over 230 mm during summer 1981 than summer 1980. These data further support the hypothesis that the drought affected the larger individuals more than the smaller ones in the population. The decrease in numbers of larger bass was a result of either high mortality or replacement of larger individuals by smaller bass from the tributaries.

In contrast to conditions in the summer, the length frequency composition remained fairly constant through the fall, winter and spring then increased in the summer. The increase from spring to summer 1981 in the percentage of larger bass (19.0% to 28.4%) was most likely due to the return of the smaller bass to the tributary streams.

The influx of smaller bass into the main river with the arrival of fall was again illustrated by the dramatic increase in the number of bass in the 81-180 mm length range (Table 29) that occurred during the period from fall to spring. The data also indicate that if smallmouth bass reach maturity at ages three or four as has been reported for other waters (Carlander 1977) then up to 36.6% of the smallmouth bass population were capable of spawning in 1980.

Sites 2 and 7 appeared to be the only sites in the summer of 1980 that could be impacted by angling pressure (Table 30). Site 2 was located near a compground and received relatively heavy fishing pressure, site 7, however, received very little pressure although it is easily accessible by vehicle. Site 7 probably is impacted because of the low productivity that exists at that site.

The site specific length frequency data from the summer of 1981 reveals that sites 1, 2, 4, and 7 had higher percentage of occurrence of bass over 230 mm in 1981 than 1980. In other sites in 1981 there was a reduction from 1980 in the percentage of large bass. This change may be due to these sites losing a larger percentage of their populations to the size-specific drought-induced mortality.

All sites had an increase in the percentage of smaller bass in the fall but sites 7, 8, and 11 had the most dramatic increases (Table 30). This increase suggested a downstream migration which did not reverse itself until summer.

Ozark Bass

Length frequency analysis failed to show any indication of overharvest in the Ozark bass population. Half of all Ozark bass captured were at least 170 mm in total length, the size where they begin to enter the creel. There is no evidence that current angling pressure is affecting the fishery. In fact, the fishery has some characteristics of an unexploited fishery.

If the Ozark bass matures at age III as does *A. rupestris* (Carlander 1977), then 84% of the population sampled was capable of spawning.

Although the numbers of Ozark bass over 170 mm did not appear to fluctuate with each season, there was variability in numbers captured in the smaller length classes particularly in the size class, 81-110 mm. The increase in the percentage of Ozark bass less than 170 mm also reflects the movement of Ozark bass out of the tributaries. The increase in the percentage of larger Ozark bass in spring would indicate the return of these younger Ozark bass to their home tributaries.

As with smallmouth bass, there was reduction in the numbers of Ozark bass in the summer of 1981 as compared with that in the summer of 1980. The change does not appear to be angler-related since the reduction in numbers occurs not just in the larger length classes but is common to all length classes.

No populations showed signs of overharvest of Ozark bass (Table 31) during summer 1980. During the summer of 1981, four sites actually showed increases in the percentage of their populations with total lengths greater than 170 mm; five others had decreases. These changes were drought-related and not due to angling pressure since all size classes not just those over 170 mm were affected.

The length frequency composition changed more dramatically between the two summers for Ozark bass than for smallmouth bass. Even though there was an apparent fall movement which caused changes in the size structure, the migration appeared to continue into the winter and was not reversed until the spring.

Mortality

Smallmouth Bass

The annual mortality rate (42%) calculated during this study was higher than the one calculated (36%) by Kilambi et al. (1977). However, the mortality I calculated was still lower than the annual mortality rates reported by Coble (1975) for other waters (Table 48). The increased mortality could reflect either some increase in fishing pressure over the five years since the original Buffalo River study or higher possibly drought-related natural mortality. However, the mortality level found was generally lower than that found for other streams and indicates that the river is not receiving the heavy pressure that other streams are. It appears, however, that sites 4 and 7 have a mortality rate nearly double that of other sites. Although it is possible that the higher mortality at site 7 is due to fishing pressure on a very low density site, it is doubtful that the higher mortality at site 4 is caused by fishing pressure since this site receives very little pressure.

Table 48. Annual mortality rates for smallmouth bass from various waters.

Locality	Annual mortality rate (%)	Source
Buffalo River, AR	42	Present study, 1981
Oneida Lake, NY	43	Forney 1972
South Bay, Lake Huron	51	Fry 1964
Red Cedar River, WI	55	Paragamian 1973
Potomac River, MD	57	Sanderson 1958
Baie du Dore, Lake Huron	57	White 1970
Plover River, WI	65	Paragamian 1973
Lake Opeongo, Ontario	53	Christie 1957
Livingston Branch,WI	55	Brynildson and Troug 1965
Little Miami River, OH	57	Brown 1960
Courtois Creek, MO	65	Fajen 1972
Huzzah Creek, MO	66	Fajen 1972

Source: Coble (1975)

Ozark Bass

Mortality rates for Ozark bass at Buffalo River were similar to those reported by Carlander (1977) for A. rupestris in Ohio streams (55 to 72%) and for Nebish Lake, Wisconsin (66 to 79%). Since Nebish Lake was not fished, rock bass and probably Ozark bass have a naturally high mortality rate. The rates for the Buffalo River would not seem to indicate that the stream was receiving high fishing pressure but would support other data to the contrary.

Conclusions

Density and standing crop of smallmouth bass and Ozark bass in Buffalo River were comparable to those in rivers and streams in Missouri and Oklahoma but were lower than those in Iowa and Wisconsin. The Buffalo River, located on the southern edge of the smallmouth bass range appears to be less than optimum smallmouth bass habitat.

The smallmouth bass/Ozark bass populations in the Buffalo River appeared to be regulated by a space-food mechanism during cyclic periods of drought. During non-drought years neither habitat or food appeared to be limiting. During low flow periods, aquatic insect and forage fish populations were reduced as were the populations of these two bass species. Cause and effect relationship could not be proven but the implication of cause and effect needs investigation.

Summer partitioning of habitat between the two species appeared to occur along the velocity axis since Ozark bass occupied areas of less current than smallmouth bass. Subtle partitioning also occurred along the substrate axis; although both species utilized boulder and bedrock areas, smallmouth bass utilized areas with cobble and cobble-boulder as their secondary substrate whereas Ozark bass utilized areas with aquatic vegetation.

Food was also partitioned within species and overlaps declined as both species increased in size. The shift of both species from insects to crayfish and minnows as they increased in size served to reduce intraspecific competition. Interspecific competition was also reduced because adult smallmouth bass utilized fish heavily whereas Ozark bass utilized crayfish and insects more heavily than minnows.

Existing levels of canoe activity appeared not to seriously impact the fishery. Few correlations between density and standing crop of either species and canoe use were found. In spring, incresed canoe levels were correlated with increased standing crop of smallmouth bass and could be interpreted as an indication that increased canoe traffic was hindering angler harvest. A negative correlation between condition factors of Ozark bass and spring canoe levels could indicate that some disturbance of Ozark bass was occurring. The positive correlation between smallmouth bass K and canoe use levels during periods of low flow could also be interpreted to indicate that harvest was having positive effects on the population.

Overharvest does not appear to be a problem as evidenced by the low mortality rate of smallmouth bass, the higher than average catch rate for smallmouth bass and the smaller proportion of younger bass in the creel compared to that in other waters.

Recommendations

1. Since the predator populations appear to be regulated by a space-food interaction, stocking of additional predators should be

avoided especially during periods of drought or stress.

2. Data on population structure and fishing pressure do not indicate any justification for stocking of additional smallmouth bass.

3. The indication of a food limited system during low flows should caution against land use or management activities that result in increased siltation of the stream or cause a reduction in the aquatic insect or minnow populations.

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APPENDIXES

APPENDIX A

STREAM FLOW DATA FOR BUFFALO RIVER, ARKANSAS

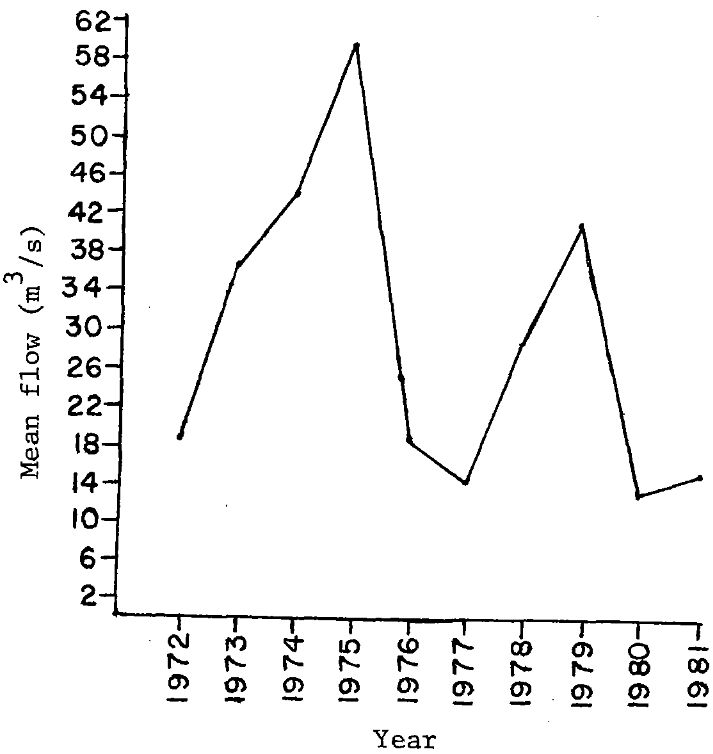

Figure 7. Mean flows (m^3/s) for the Buffalo River, Arkansas for the period 1972-1981. Flows were measured at the highway 65 bridge. (Source: U.S. Geological Survey)

APPENDIX B

SUBSTRATE TYPES, WATER DEPTHS AND VELOCITIES

AT EACH SAMPLE SITE

Table 49. Percent occurrence of each substrate type at each of 12 sample sites on the Buffalo River, Arkansas.

Site number	Silt	Sand	Pebble	Gravel	Cobble	Boulder	Bedrock	Detritus	Vegetation
1	21.5	23.6	0.7	46.7	42.3	4.7	8.0	3.4	2.7
2	1.4	5.1	14.8	52.7	12.9	20.8	7.5	1.7	0.0
3	29.1	1.6	17.0	70.0	32.8	8.9	6.7	9.4	0.2
4	18.2	3.0	25.7	58.0	11.8	8.4	28.2	0.0	0.3
5	15.8	19.8	25.1	75.2	30.6	6.8	1.7	4.9	2.0
6	13.2	11.6	45.7	60.4	12.9	11.3	18.8	0.4	15.1
7	55.3	34.2	11.8	37.0	7.5	0.3	31.7	0.0	0.0
8	21.1	12.5	31.9	64.2	10.6	9.7	10.2	0.0	8.7
9	13.5	1.9	36.9	61.9	11.1	5.8	30.4	0.0	7.5
10	7.3	3.1	17.6	42.8	8.1	4.8	48.4	1.5	5.0
11	17.2	15.1	39.3	57.6	10.9	15.6	10.8	1.2	8.7
12	3.7	35.6	35.8	69.9	27.2	1.6	3.1	2.5	8.7

Table 50. Proportion of each velocity interval present at each of 12 sample sites on the Buffalo River, Arkansas.

Site	Velocity (cm/s) 0	1-10	11-20	21+
1	23.3	36.7	24.8	15.3
2	79.3	17.7	2.5	0.5
3	95.7	2.9	1.4	0.0
4	85.5	12.5	1.5	0.4
5	56.5	27.8	4.7	12.6
6	62.1	31.1	1.0	5.8
7	40.8	46.0	9.4	3.4
8	65.0	16.2	13.6	5.4
9	23.7	39.5	14.2	22.3
10	31.5	21.0	27.0	10.7
11	62.8	12.4	13.8	6.4
12	45.7	23.8	21.1	9.5

Table 51. Proportion of each depth interval present at each of 12 sample sites on the Buffalo River, Arkansas.

Site	Depth (m)				
	≤ 0.25	0.26-0.75	0.76-1.25	1.26-1.75	1.76+
1	15.1	38.9	22.1	17.1	6.8
2	45.5	31.5	11.3	10.9	0.7
3	13.1	41.5	24.7	10.6	10.1
4	12.6	36.8	33.8	9.5	7.3
5	31.1	29.7	24.6	14.0	0.6
6	26.8	35.4	14.3	17.5	5.9
7	6.1	27.6	32.3	21.0	12.9
8	15.0	37.3	20.3	22.2	5.2
9	28.2	31.9	36.8	3.1	0.0
10	16.0	58.0	20.0	6.0	0.0
11	13.9	43.0	29.1	7.6	6.3
12	35.3	39.8	18.8	6.2	0.0

APPENDIX C

DATES OF SAMPLING EFFORT

Table 52. Dates that each of 12 sites on the Buffalo River, Arkansas were sampled by electroshocking.

Season	Site 1	2	3	4	5	6	7	8	9	10	11	12
Summer 1980	06-30	07-17	07-03	07-18	-	08-04	07-01	07-07	07-24	07-14	-	07-02
Summer 1980	07-03	08-08	08-01	08-07	08-05	09-05	07-21	07-25	-	07-28	07-29	07-22
Summer 1980	09-09	09-16	09-15	09-08	09-29	09-30	-	09-18	09-19	09-12	09-11	-
Fall 1980	10-24	11-28	11-07	11-22	10-31	11-14	11-06	11-26	-	-	10-30	-
Winter 1980	12-19	12-31	12-23	12-30	12-18	01-07	12-22	12-29	01-05	12-12	12-11	12-05
Spring 1981	03-17	03-31	04-10	03-26	04-02	03-09	04-06	03-12	03-19	04-16	03-11	03-07
Summer 1981	06-05	06-12	06-08	07-01	06-23	06-15	06-24	06-22	07-02	06-29	07-17	06-25
Summer 1981	07-07	07-08	07-21	07-21	07-14	07-09	07-31	07-29	07-23	08-13	07-27	08-07
Summer 1981	07-28	07-30	08-06	08-10	08-12	09-02	08-11	09-03	08-27	08-26	08-14	-

APPENDIX D

MEAN WEIGHTS FOR SMALLMOUTH BASS

AND OZARK BASS

Table 53. Cumulative seasonal mean weights of smallmouth bass and Ozark bass. Numbers in parenthesis represent the 95% confidence intervals for the mean.

Season	Mean weight (g)	
	Smallmouth bass	Ozark bass
Summer 1980	183.0 N=709 (166.1-199.9)	(106.8 N=1092 (102.5-111.1)
Fall	103.9 N=542 (90.8-117.0)	102.0 N=287 (93.2-110.8)
Winter	124.1 N=440 (101.2-147.0)	74.8 N=340 (66.8-82.8)
Spring	115.7 N=373 (92.5-138.8)	98.5 N=300 (88.7-108.3)
Summer 1981	140.4 N=275 (114.5-166.3)	90.3 N=791 (84.8-95.8)

Table 54. Seasonal mean weights of smallmouth bass from 12 sites on Buffalo River, Arkansas. Numbers enclosed in parentheses represents 95% confidence intervals for the mean.

Site	Mean weight (g), smallmouth bass				
	Summer 1980	Fall 1980	Winter 1980	Spring 1981	Summer 1981
1	173.6 N=72 (120.8-226.4)	141.1 N=24 (79.4-202.8)	82.5 N=28 (11.5-153.5)	80.1 N=15 (37.0-137.2)	248.6 N=29 (158.6-338.6)
2	161.3 N=92 (104.5-218.1)	69.5 N=31 (42.5-96.5)	17.4 N=18 (10.4-24.4)	298.1 N=9 (38.0-558.2)	138.8 N=58 (98.7-178.9)
3	222.1 N=44 (158.3-285.9)	79.1 N=32 (37.0-121.2)	154.5 N=25 (106.0-203.0)	281.5 N=25 (0-615.0)	42.5 N=8 (0-91.2)
4	159.6 N=65 (105.6-213.6)	125.0 N=18 (29.4-220.6)	71.2 N=26 (21.1-121.3)	296.8 N=18 (133.7-459.9)	381.4 N=22 (159.3-603.5)
5	180.7 N=30 (117.5-243.9)	78.9 N=14 (42.2-115.6)	17.4 N=7 (7.9-26.9)	172.7 N=3 (0-809.1)	112.5 N=8 (16.0-209.0)
6	194.5 N=96 (146.9-242.1)	84.9 N=30 (38.5-131.3)	114.7 N=90 (84.1-145.3)	29.7 N=31 (18.7-40.7)	75.4 N=13 (10.8-140.0)
7	140.3 N=20 (44.0-236.6)	57.8 N=94 (41.4-74-4)	40.0 N=73 (0-84.9)	57.5 N=45 (0-121.1)	82.2 N=35 (44.0-120.4)
8	186.2 N=57 (118.3-254.1)	48.4 N=53 (20.5-76.3)	168.4 N=23 (0-365.2)	66.2 N=28 (10.8-121.6)	94.8 N=18 (46.7-142.9)

Table 54. Continued.

Site	Mean weight (g) smallmouth bass				
	Summer 1980	Fall 1980	Winter 1980	Srping 1981	Summer 1981
9	238.7 N=88 (186.9-290.5)	201.4 N=129 (162.2-204.6)	256.3 N=87 (177.3-335.3)	197.4 N=105 (142.5-252.3)	231.0 N=10 (55.9-406.1)
10	221.3 N=60 (139.9-285.7)	- -	286.0 N=18 (91.2-480.8)	42.3 N=14 (0-84.6)	36.2 N=17 (18.6-53.8)
11	124.1 N=78 (94.5-153.7)	71.6 N=117 (52.4-90.8)	22.5 N=38 (9.7-45.3)	50.1 N=97 (20.6-79.6)	86.2 N=53 (44.2-128.2)
12	111.4 N=7 (42.6-179.2)	- -	105.3 N=7 (20.7-191.9)	78.0 N=1 -	165.5 N=4 (138.1-192.9)

Table 55. Seasonal mean weights for Ozark bass from 12 sites on Buffalo River, Arkansas. Numbers in parentheses represent the 95% confidence intervals for the mean.

	Mean weight (g) Ozark bass				
Site	Summer 1980	Fall 1980	Winter 1980	Srping 1981	Summer 1981
1	127.2 N=14 (96.7-157.7)	117.3 N=4 (49.8-184.8)	130.0 N=20 (95.9-164.1)	128.2 N=42 (107.2-148.2)	116.9 N=38 (92.5-141.3)
2	102.4 N=69 (84.3-120.5)	53.0 N=18 (10.8-95.2)	22.6 N=25 (11.2-34.0)	106.2 N=13 (10.8-95.2)	130.9 N=74 (84.3-120.5)
3	98.6 N=43 (71.1-122.5)	13.2 N=22 (63.1-143.3)	55.0 N=14 (10.3-99.7)	137.7 N=6 (16.3-259.1)	101.5 N=11 (50.5-152.5)
4	112.1 N=59 (93.5-130.7)	72.3 N=9 (25.9-118.7)	40.2 N=18 (20.6-59.8)	204.0 N=2 (153.2-254.8)	96.5 N=19 (62.9-130.1)
5	127.2 N=142 (114.1-140.3)	95.2 N=18 (61.7-128.7)	12.0 N=3 (0-25.3)	115.8 N=19 (80.5-151.1)	95.4 N=72 (75.5-115.3)
6	110.9 N=289 (102.1-119.7)	109.7 N=68 (90.8-128.6)	80.4 N=106 (63.6-97.2)	62.0 N=54 (39.0-85.0)	88.4 N=136 (71.7-105.1)
7	116.4 N=30 (90.3-142.5)	115.6 N=45 (98.5-132.7)	38.4 N=27 (18.9-57.9)	118.9 N=41 (94.6-143.2)	90.0 N=77 (74.4-105.3)
8	83.4 N=141 (74.4-92.4)	76.2 N=41 (52.5-99.8)	30.8 N=31 (17.7-43.9)	56.4 N=31 (34.6-78.2)	92.4 N=100 (77.3-107.5)

Table 55. Continued.

Site	Mean weight (g) Ozark bass Summer 1980	Fall 1980	Winter 1980	Srping 1981	Summer 1981
9	114.2 N=98 (101.9-126.5)	148.1 N=26 (120.3-175.9)	110.8 N=74 (93.7-127.9)	104.1 N=28 (71.5-136.7)	82.0 N=91 (69.3-94.7)
10	96.7 N=61 (80.1-113.3)	- -	138.0 N=8 (86.9-189.1)	143.9 N=31 (111.6-176.2)	97.7 N=41 (76.1-119.3)
11	95.8 N=112 (84.1-107.5)	92.8 N=36 (68.4-117.2)	66.8 N=12 (33.8-99.8)	61.5 N=26 (32.0-91.0)	59.3 N=132 (49.3-69.3)
12	33.7 N=5 (17.7-49.9)	- -	64.0 N=2 (0-165.6)	58.3 N=7 (0-184.6)	- -

APPENDIX E

SEASONAL UTILIZATION OF SPECIFIC SUBSTRATE

TYPES OF SMALLMOUTH BASS AND

OZARK BASS

Table 56. Substrate codes used to define substrate at each of 12 sites on the Buffalo River, Arkansas.

Code	Substrate type	Code	Substrate type
1	Silt only	23	Pebble and detritus
2	Silt and sand	24	Pebble and vegetation
3	Silt and pebble	25	Gravel only
4	Silt and gravel	26	Gravel and cobble
5	Silt and cobble	27	Gravel and boulder
6	Silt and boulder	28	Gravel and bedrock
7	Silt and bedrock	29	Gravel and detritus
8	Silt and detritus	30	Gravel and vegetation
9	Silt and vegetation	31	Cobble only
10	Sand only	32	Cobble and boulder
11	Sand and pebble	33	Cobble and bedrock
12	Sand and gravel	34	Cobble and detritus
13	Sand and cobble	35	Cobble and vegetation
14	Sand and boulder	36	Boulder only
15	Sand and bedrock	37	Boulder and bedrock
16	Sand and detritus	38	Boulder and detritus
17	Sand and vegetation	39	Boulder and vegetation
18	Pebble only	40	Bedrock only
19	Pebble and gravel	41	Bedrock and detritus
20	Pebble and cobble	42	Bedrock and vegetation
21	Pebble and boulder	43	Detritus only
22	Pebble and bedrock	44	Detritus and vegetation

Table 57. Frequency of occurrence and percentage of total captures of smallmouth bass over specific substrate types.

Substrate	Summer 1980 N	Summer 1980 %	Fall 1980 N	Fall 1980 %	Winter 1980 N	Winter 1980 %	Spring 1981 N	Spring 1981 %	Summer 1981 N	Summer 1981 %
1	14	1.8	5	1.3	10	5.4	1	0.6	7	4.1
2	5	0.7	2	0.5	0	0.0	8	4.9	3	1.7
3	4	0.5	0	0.0	1	0.5	0	0.0	0	0.0
4	8	1.1	5	1.3	0	0.0	1	0.6	2	1.2
5	12	1.6	4	1.1	1	0.5	1	0.6	2	1.2
6	24	3.2	11	3.0	10	5.4	0	0.0	0	0.0
7	37	4.9	33	8.9	20	10.8	1	0.6	0	0.0
8	4	0.5	0	0.0	0	0.0	7	4.3	0	0.0
9	2	0.3	1	0.3	2	1.1	1	0.6	2	1.2
10	2	0.3	0	0.0	0	0.0	1	0.6	1	0.6
11	5	0.7	0	0.0	0	0.0	0	0.0	1	0.6
12	5	0.7	1	0.3	5	2.7	0	0.0	2	1.2
13	3	0.4	1	0.3	3	1.6	0	0.0	0	0.0

Table 57. Continued.

Substrate	Summer 1980		Fall 1980		Winter 1980		Spring 1981		Summer 1981	
	N	%	N	%	N	%	N	%	N	%
14	7	0.9	0	0.0	1	0.5	5	3.1	0	0.0
15	3	0.4	1	0.3	0	0.0	1	0.6	1	0.6
16	4	0.5	0	0.0	0	0.0	0	0.0	1	0.6
17	0	0.0	0	0.0	0	0.0	0	0.0	3	1.7
18	0	0.0	0	0.0	1	0.5	0	0.0	0	0.0
19	8	1.1	5	1.3	0	0.0	2	1.2	1	0.6
20	12	1.7	1	0.3	1	0.5	9	5.5	2	1.2
21	10	1.3	1	0.3	0	0.0	3	1.8	2	1.2
22	2	0.3	0	0.0	0	0.0	2	1.2	1	0.6
23	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
24	2	1.3	0	0.0	0	0.0	0	0.0	0	0.0
25	28	3.7	1	0.3	1	0.5	1	0.6	10	5.8
26	64	8.4	31	8.3	7	3.8	2	1.2	12	7.0
27	36	4.8	13	3.5	3	1.6	4	2.4	5	2.9

Table 57. Continued.

Substrate	Summer 1980 N	Summer 1980 %	Fall 1980 N	Fall 1980 %	Winter 1980 N	Winter 1980 %	Spring 1981 N	Spring 1981 %	Summer 1981 N	Summer 1981 %
28	14	1.8	11	3.0	1	0.5	1	0.6	1	0.6
29	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
30	7	0.9	0	0.0	1	0.5	0	0.0	3	1.7
31	23	3.0	1	0.3	8	4.3	0	0.0	10	5.8
32	89	11.7	49	13.2	20	10.8	13	7.9	36	20.9
33	16	2.1	15	4.0	6	3.2	5	3.1	3	1.7
34	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
35	3	0.4	0	0.0	1	0.5	0	0.0	0	0.0
36	80	10.5	16	4.3	7	3.8	18	11.0	19	11.1
37	84	11.0	66	17.7	32	17.2	44	26.8	16	9.3
38	3	0.4	0	0.0	0	0.0	0	0.0	2	1.2
39	11	1.5	2	0.5	0	0.0	0	0.0	0	0.0
40	125	15.4	92	24.7	43	23.1	29	17.7	22	12.8

Table 57. Continued.

Substrate	Summer 1980		Fall 1980		Winter 1980		Spring 1981		Summer 1981	
	N	%	N	%	N	%	N	%	N	%
41	0	0.0	4	1.1	0	0.0	1	0.6	0	0.0
42	3	0.4	0	0.0	0	0.0	2	1.2	1	0.6
43	1	0.1	0	0.0	0	0.0	0	0.0	1	0.6
44	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	761		372		185		163		172	

Table 58. Frequency of occurrence and percentage of total captures of Ozark bass over specific substrate types during winter 1980 and summer 1981.

Substrate	Winter 1980 N	Winter 1980 % of Total	Summer 1981 N	Summer 1981 % of Total
1	6	6.0	20	4.1
2	0	0.0	1	0.2
3	0	0.0	1	0.2
4	0	0.0	1	0.2
5	0	0.0	3	0.6
6	2	2.0	7	1.4
7	7	7.0	0	0.0
8	0	0.0	0	0.0
9	3	3.0	3	0.6
10	0	0.0	1	0.2
11	1	1.0	0	0.0
12	1	1.0	6	1.2
13	0	0.0	1	0.2
14	1	1.0	2	0.4
15	0	0.0	0	0.0
16	0	0.0	2	0.4
17	0	0.0	4	0.8
18	0	0.0	9	1.9
19	0	0.0	4	0.8
20	1	1.0	0	0.0

Table 58. Continued.

Substrate	Winter 1980 N	Winter 1980 % of Total	Summer 1981 N	Summer 1981 % of Total
21	0	0.0	6	1.2
22	0	0.0	1	0.2
23	0	0.0	0	0.0
24	0	0.0	2	0.4
25	1	1.0	12	2.5
26	6	6.0	11	2.3
27	3	3.0	9	1.9
28	0	0.0	1	0.2
28	0	0.0	0	0.0
30	0	0.0	8	1.6
31	7	7.0	15	3.1
32	15	15.0	60	12.3
33	0	0.0	3	0.6
34	0	0.0	0	0.0
35	1	1.0	3	0.6
36	6	6.0	98	20.1
37	14	14.0	93	19.1
38	0	0.0	3	0.6
39	0	0.0	25	5.1
40	24	24.0	59	12.1
41	1	1.0	0	0.0

Table 58. Continued.

Substrate	Winter 1980 N	Winter 1980 % of Total	Summer 1981 N	Summer 1981 % of Total
42	0	0.0	11	2.3
43	0	0.0	0	0.0
44	0	0.0	0	0.0

APPENDIX F

SEASONAL CONDITION COEFFICIENTS FOR

SMALLMOUTH BASS AND OZARK BASS

Table 59. Mean condition coefficients for smallmouth bass of Buffalo River, Arkansas, by season and site. Numbers in parentheses are sample sizes; numbers in brackets are the 95% confidence intervals for the mean.

Site	Summer 1980	Fall 1980	Winter 1980	Spring 1981	Summer 1981
1	1.59 (N=72) [1.25-1.93]	1.71 (N=24) [1.32-2.10]	1.02 (N=29) [0.96-1.08]	1.08 (N=15) [0.97-1.19]	1.24 (N=29) [1.18-1.30]
2	1.26 (N=29) [1.16-1.36]	1.14 (N=32) [1.06-1.22]	1.21 (N=18) [1.04-1.38]	1.18 (N=9) [1.11-1.25]	1.20 (N=58) [1.10-1.30]
3	1.47 (N=44) [1.27-1.67]	1.28 (N=32) [0.97-1.59]	1.05 (N=25) [1.01-1.09]	1.09 (N=6) [0.91-1.27]	1.04 (N=6) [0.57-1.51]
4	1.52 (N=65) [1.34-1.70]	1.18 (N=18) [1.10-1.26]	1.14 (N=26) [1.08-1.20]	1.16 (N=18) [1.05-1.27]	1.26 (N=22) [1.18-1.34]
5	1.29 (N=30) [1.19-1.39]	1.69 (N=14) [0.80-2.58]	0.85 (N=7) [0.65-1.05]	1.03 (N=3) [0-2.06]	1.11 (N=8) [0.85-1.37]
6	1.54 (N=96) [1.42-1.66]	1.94 (N=30) [1.49-2.39]	1.17 (N=90) [1.13-1.21]	1.31 (N=31) [1.17-1.45]	1.12 (N=13) [0.95-1.29]
7	1.84 (N=20) [1.51-2.17]	1.35 (N=94) [1.27-1.43]	1.07 (N=73) [1.01-1.13]	1.20 (N=45) [1.06-1.34]	1.95 (N=35) [1.58-2.32]
8	1.27 (N=57) [1.19-1.35]	1.03 (N=35) [0.97-1.09]	1.01 (N=23) [0.91-1.11]	1.09 (N=28) [1.03-1.15]	1.13 (N=18) [1.07-1.19]
9	1.25 (N=88) [1.19-1.31]	1.20 (N=129) [1.14-1.26]	1.17 (N=87) [1.13-1.21]	1.20 (N=105) [1.16-1.24]	1.19 (N=10) [1.05-1.33]

Table 59. Continued.

Site	Summer 1980	Fall 1980	Winter 1980	Spring 1981	Summer 1981
10	1.46 (N=60) [1.28-1.64]	- -	1.77 (N=18) [1.39-2.15]	1.09 (N=14) [1.00-1.18]	1.15 (N=17) [0.94-1.36]
11	1.66 (N=78) [1.40-1.92]	1.29 (N=117) [1.33-1.45]	0.99 (N=38) [0.91-1.07]	1.23 (N=97) [1.19-1.27]	1.17 (N=53) [1.11-1.23]
12	1.67 (N=7) [1.18-2.16]	- -	1.00 (N=7) [0.88-1.12]	1.29 (N=1) [1.29]	1.22 (N=4) [1.09-1.35]

Table 60. Mean condition coefficients for Ozark bass in Buffalo River, Arkansas, by site and season. Numbers in parentheses are sample sizes; numbers in brackets are the 95% confidence intervals for the mean.

Site	Summer 1980	Fall 1980	Winter 1980	Spring 1981	Summer 1981
1	2.15 (N=43) [1.94-2.38]	2.23 (N=4) [2.01-2.45]	1.60 (N=20) [1.39-1.81]	1.71 (N=42) [1.59-1.83]	2.58 (N=38) [1.32-3.84]
2	1.88 (N=69) [1.62-2.14]	1.50 (N=18) [1.29-1.71]	16.2 (N=25) [1.48-1.76]	2.21 (N=13) [1.90-2.51]	1.96 (N=74) [1.90-2.02]
3	2.32 (N=43) [1.98-2.66]	1.56 (N=22) [1.35-1.77]	1.56 (N=14) [1.34-1.78]	2.03 (N=6) [1.57-2.49]	1.89 (N=11) [1.78-2.00]
4	1.92 (N=59) [1.82-2.02]	2.00 (N=9) [1.70-2.30]	1.66 (N=18) [1.53-1.79]	2.06 (N=2) [0.41-3.71]	1.84 (N=19) [1.67-2.01]
5	2.06 (N=142) [2.00-2.12]	2.32 (N=18) [1.88-2.76]	1.54 (N=3) [0.25-2.83]	1.99 (N=19) [1.68-2.20]	2.76 (N=72) [1.76-3.76]
6	2.24 (N=289) [2.08-2.40]	2.17 (N=68) [1.99-2.35]	1.84 (N=106) [1.76-1.92]	1.90 (N=54) [1.78-2.02]	1.98(N=136) [1.88-2.08]
7	3.20 (N=30) [2.46-2.94]	2.03 (N=45) [1.87-2.19]	1.58 (N=27) [1.44-1.72]	1.98 (N=41) [1.90-2.06]	1.87 (N=77) [1.77-1.97]
8	2.26 (N=141) [2.04-2.48]	1.69 (N=41) [1.63-1.75]	1.70 (N=31) [1.60-1.80]	1.88 (N=31) [1.82-1.94]	1.86(N=100) [1.78-1.94]
9	2.99 (N=98) [1.91-2.07]	1.79 (N=26) [1.63-1.95]	1.79 (N=74) [1.73-1.85]	1.86 (N=28) [1.78-1.94]	1.91 (N=91) [1.81-2.01]

Table 60. Continued.

Site	Summer 1980	Fall 1980	Winter 1980	Spring 1981	Summer 1981
10	1.98 (N=61) [1.82-2.14]	- -	2.05 (N=8) [1.53-2.57]	1.95 (N=31) [1.85-2.05]	1.70 (N=41) [1.64-1.76]
11	2.05 (N=112) [1.89-2.21]	2.02 (N=36) [1.86-2.18]	1.63 (N=12) [1.52-1.74]	1.96 (N=26) [1.88-2.04]	2.02(N=132) [1.39-2.65]
12	4.95 (N=5) [3.26-6.64]	- -	1.55 (N=2) [1.30-1.80]	2.60 (N=7) [2.14-3.06]	- -

APPENDIX G

CUMULATIVE MEAN TOTAL LENGTH AND ANNUAL
GROWTH INCREMENTS FOR SMALLMOUTH
BASS AND OZARK BASS

Table 61. Total length (mm) at age and annual growth increments of smallmouth bass in Buffalo River, Arkansas. Sample sizes are given in parentheses.

	Mean calculated total length (mm) at each annulus							
	I	II	III	IV	V	VI	VII	VIII
1980	97.2 (133)							
1979	107.7 (323)	154.2 (81)						
1978	113.8 (372)	160.9 (365)	206.1 (71)					
1977	126.2 (283)	181.0 (283)	223.1 (283)	257.9 (36)				
1976	121.4 (137)	151.5 (137)	221.9 (137)	265.1 (137)	294.7 (26)			
1975	123.1 (39)	178.5 (39)	231.5 (39)	279.8 (39)	326.3 (38)	370.0 (8)		
1974	125.7 (14)	178.6 (14)	237.6 (14)	287.3 (14)	330.0 (14)	361.0 (14)	424.4 (3)	
1973	136.9 (10)	191.2 (7)	226.2 (10)	266.9 (10)	323.7 (10)	366.4 (10)	406.3 (10)	406.7 (1)
1972	112.9 (3)	165.1 (4)	224.0 (4)	270.7 (4)	354.9 (4)	390.0 (3)	420.2 (4)	446.9 (4)
Mean Length	114.7 (1314)	166.3 (930)	221.7 (558)	267.9 (240)	318.9 (92)	367.1 (35)	412.8 (17)	438.9 (5)
Mean Growth Increment	0 114.7	I 51.6	II 55.4	III 46.2	IV 51.0	V 48.2	VI 45.7	VII 26.1

Table 62. Total length (mm) at age and annual growth increments attained by Ozark bass in Buffalo River, Arkansas. Sample sizes are given in parentheses.

		Mean calculated total length (mm) at each annulus						
	I	II	III	IV	V	VI	VII	VIII
1980	52.1 (118)							
1979	52.2 (338)	91.1 (264)						
1978	54.7 (167)	87.1 (275)	138.7 (111)					
1977	54.9 (186)	93.7 (421)	124.1 (413)	176.3 (151)				
1976	55.8 (98)	95.1 (427)	124.6 (427)	153.6 (425)	196.0 (58)			
1975	53.3 (20)	96.1 (254)	122.3 (254)	151.7 (254)	179.0 (253)	218.8 (13)		
1974	56.3 (7)	98.5 (97)	124.4 (97)	153.5 (97)	184.4 (97)	209.6 (95)	231.0 (7)	
1973		95.9 (4)	116.6 (4)	144.7 (4)	177.8 (4)	208.2 (4)	224.8 (4)	
1972		95.7 (2)	119.3 (2)	150.8 (2)	200.3 (2)	227.0 (2)	242.7 (2)	256.4 (2)
Mean Length	53.3 (940)	93.2 (1744)	125.1 (1308)	156.7 (933)	182.7 (414)	210.9 (114)	230.9 (13)	256.4 (2)
Mean Growth	0	I	II	III	IV	V	VI	VII
Increment	53.3	39.9	31.9	31.6	26.0	28.2	20.0	25.5

APPENDIX H

CORRELATIONS BETWEEN SMALLMOUTH BASS DENSITY AND VARIOUS HABITAT VARIABLES

Correlations Between Smallmouth Bass Density and Habitat Variables

Summer Negative Correlations:

1) Area, A, in hectares, comprising the sample site:

1980 $\ln N = 3.23 - 0.48 \ln A$ where N = smallmouth bass density

1981 $\ln N = 1.85 - 0.82 \ln A$

2) Percent of site with a depth between 0.76 m and 1.25 m, (D_m):

1980 $N = 246.78 - 68.33 \ln D_m$

1981 $N = 128.13 - 37.20 \ln D_m$

3) Percent of site with silt substrate, (S_s):

1980 $N = 102.37 - 26.87 \ln S_s$

1981 $N = 51.33 - 15.34 \ln S_s$

4) Percent of site covered with aquatic vegetation, (V):

1981 $N = 8.72 - 2.20 \ln V$

Summer Positive Correlations:

1) Gradient, (G), of river at sample site in meters/kilometer:

1980 $N = 3.01 + 0.88 \ln G$

1981 $N = 1.45 + 1.67 \ln G$

2) Maximum depth of pool in meters, (D_x):

1980 $N = -33.80 + 28.73 D_x$

1981 $\ln N = 0.45 + 1.08 D_x$

3) Percent of site with a depth less than 0.26 meters, (D_s):

1980 $N = -13.85 + 2.18 D_s$

1981 $N = -12.21 + 1.12 D_s$

4) Percent of site with boulder substrate, (S_b):

1980 $N = 3.92 + 1.06\ S_b$

1981 $N = -4.80 + 2.03\ S_b$

5) Percent of site with a cobble and boulder substrate, (S_{cb}):

1980 $\ln N = 0.10 + 0.97 \ln S_{cb}$

Fall Positive Correlation:

Maximum depth of pool in meters, (D_x):

$$\ln N = 1.40 + 0.87\ D_x$$

Winter Negative Correlation:

Percent of site with a depth between 0.26 m and 0.75 m (D_t):

$$\ln N = 6.21 - 0.07\ D_t$$

Spring Positive Correlation:

Maximum depth of pool in meters, (D_x):

$$N = -9.67 + 13.74\ D_x$$

APPENDIX I

CORRELATIONS BETWEEN DENSITY OF OZARK BASS AND VARIOUS HABITAT VARIABLES

Correlations Between Ozark Bass Density and Habitat Variables

Summer Negative Correlations:

1) Percent of site with a depth, D_m, of 0.76 m to 1.25 m:

1980 $N = 268.97 - 74.06 \ln D_m$ where N = Density of Ozark Bass

1981 $N = 167.33 - 46.44 \ln D_m$

2) Percent of site with a bedrock substrate, S_r:

1980 $\ln N = 3.91 - 0.04 S_r$

Summer Positive Correlations:

1) Percent of site with a depth, D_s, less than 0.26 m:

1980 $N = -12.98 + 2.34 D_s$

1981 $N = -8.63 + 1.43 D_s$

2) Percent of site with boulder substrate, S_b:

1980 $N = 7.23 + 3.68 S_b$

Fall Negative Correlations:

1) Percent of site with a current velocity, V_{11}, of 11-20 cm/s

$N = 60.49 - 17.09 \ln V_{11}$

1) Percent of site with a depth, D_m, of 0.76 m to 1.25 m:

$N = 108.26 - 3.01 D_m$

Fall Positive Correlation:

Percent of site with a depth, D_s, of less than 0.26 m:

$N = 3.57 + 1.69 D_s$

Winter None

<u>Spring Negative Correlations:</u>

1) Area, A, of the site in hectares:

$$N = 34.39 - 14.04 \ln A$$

2) Percent of site with a depth, D_m, of 0.76 m to 1.25 m:

$$\ln N = 5.23 - 0.09 D_m$$

<u>Spring Positive Correlation:</u>

Gradient, G, of site in m/km:

$$N = -1.39 + 24.17 G$$

APPENDIX J

CORRELATIONS BETWEEN STANDING CROP OF

SMALLMOUTH BASS AND VARIOUS

HABITAT VARIABLES

Correlations Between Standing Crop of Smallmouth Bass and Habitat Variables

Summer Negative Correlations:

1) Area, A, comprising the sample site in hectares:

1980 $\ln SC = 1.87 - 0.25 A$ where SC = standing crop of smallmouth bass in kg/ha

1981 $SC = 2.16 - 1.62 \ln A$

2) Percent of site with silt substrate, (S_s):

1980 $SC = 16.31 - 4.11 \ln S_s$

3) Percent of site with a depth between 0.76 m and 1.25 m (D_m)

1980 $SC = 39.10 - 10.68 \ln D_m$

Summer Positive Correlations:

4) Gradient, (G), of river at sample site in m/km

1981 $\ln SC = -2.41 + 1.45 G$

5) Maximum depth of pool in meters, (D_x)

1981 $SC = 8.26 + 0.50 D_x$

6) Percent of site with bedrock substrate, S_r

1980 $SC = 0.41 + 0.65 S_r$

7) Percent of site with a depth less than 0.26 m, D_s

1980 $SC = -1.81 + 0.35 D_s$

Fall Positive Correlations:

1) Gradient, (G), of river at sample site in m/km

$SC = 1.59 + 3.80 G$

2) Maximum depth of pool in meters, D_x

$\ln SC = -0.94 + 0.78 D_x$

Winter   Positive Correlation:

Percent of site with a velocity, V_{20}, greater than 20 cm/sec

$$SC = 1.32 + 0.48\ V_{20}$$

Spring   Negative Correlation:

Percent of pool with silt and sand substrate, S

$$SC = 16.87 - 4.23 \ln S$$

APPENDIX K

CORRELATIONS BETWEEN STANDING CROP OF OZARK BASS AND VARIOUS HABITAT VARIABLES

Correlations Between Standing Crop of Ozark Bass

and Habitat Variables

Summer Negative Correlations:

1) Percent of site with a depth between 0.76 m and 1.25 m, D_m

1980 $SC = 26.70 - 7.26 \ln D_m$ where SC = Ozark bass standing crop in kg/ha

1981 $SC = 21.60 - 6.15 \ln D_m$

2) Percent of site with a depth greater than 1.76 m, D_d

1981 $SC = 6.80 - 2.59 \ln D_d$

3) Percent of site with a velocity between 11 cm/sec and 20 cm/sec, V_{11}

1980 $\ln SC = 4.99 - 0.07 V_{11}$

Summer Positive Correlations:

4) Percent of site with a depth less than 0.26 m, D_s

1980 $SC = 1.18 + 0.24 D_s$

1981 $SC = 1.67 + 0.19 D_s$

5) Maximum depth of pool in meters, D_x

1981 $SC = -3.63 + 2.57 D_x$

Fall None

Winter None

Spring Negative Correlations

1) Area (A) comprising the site in hectares

$\ln SC = 3.87 - 0.32 A$

Spring Positive Correlations:

2) Gradient, G, at site in m/km

$$SC = -0.63 + 2.72\ G$$

3) Percent of site with a cobble and boulder substrate, S_{cb}

$$SC = -1.01 + 0.17\ S_{cb}$$

4) Percent of site with a cobble substrate, S_x

$$SC = 0.28 + 0.16\ S_x$$

APPENDIX L

CORRELATIONS BETWEEN COEFFICIENTS OF

CONDITION OF SMALLMOUTH BASS AND

OZARK BASS AND VARIOUS

HABITAT VARIABLES

Correlations Between K Factors of Smallmouth Bass and Habitat Variables

Summer Negative Correlations:

1) Percent of site with a depth less than 0.26 m, D_s

1980 $K = 2.06 + 0.20 \ln D_s$ where K = coefficient of condition

2) Percent of site with boulder substrate, S_b

1980 $K = 1.67 - 0.11 S_b$

1981 $K = 1.53 - 0.17 S_b$

3) Percent of site with gravel and cobble substrate, S_x

1981 $K = 2.13 - 0.01 S_x$

4) Percent of site with gravel substrate, S_g

1981 $K = 4.30 - 0.76 \ln S_g$

5) Percent of site with aquatic vegetation, V

1981 $K = 1.22 - 0.04 V$

Summer Positive Correlations:

6) Mean Depth, D_m, of site in meters

1980 $K = 1.10 + 0.52 D_m$

1981 $K = 0.65 + 0.78 D_m$

7) Percent of site with silt substrate, S_s

1981 $K = 1.01 + 0.01 S_s$

8) Percent of site with sand substrate, S_a

1980 $K = 1.35 + 0.01 S_a$

9) Percent of site with silt and sand substrate, S

1980 $\ln K = 0.25 + 0.01 S$

1981 $K = 0.93 + 0.01 S$

10) Percent of site with a velocity of 1-10 cm/s, V_l

1981 $\ln K = 0.01 + 0.01\ V_l$

11) Percent of site with a depth greater than 1.75 m, D_d

1980 $K = 1.37 + 0.03\ D_d$

Fall No Correlations

Winter Negative Correlations:

1) Percent of site with gravel and cobble substrate, S_x

$\ln K = 0.65 - 0.01\ S_x$

2) Percent of site with silt and sand substrate, S

$K = 1.85 - 0.22 \ln S$

Winter Positive Correlations:

3) Percent of site with a depth of 0.26 to 0.75 m, D_t

$K = 0.40 + 0.02\ D_t$

4) Percent of site with bedrock substrate, S_r

$K = 0.91 + 0.01\ S_r$

5) Percent of site with boulder and bedrock substrate, S_e

$\ln K = -0.17 + 0.01\ S_e$

Spring Positive Correlation:

Percent of site with pebble substrate, S_p

$K = 1.06 + 0.004\ S_p$

Correlations Between K Factors of Ozark Bass and Habitat Variables

Summer Negative Correlations:

1) Percent of site with boulder substrate, S_b

1980 $K = 3.27 - 0.49 \ln S_b$ where K = coefficient of condition

2) Percent of site with bedrock substrate, S_r

1981 $K = 2.71 - 0.26 \ln S_r$

3) Percent of site with boulder and bedrock substrate, S_e

1981 $K = 3.70 - 0.53 S_e$

Summer Positive Correlations:

4) Percent of site with sand substrate, S_a

1980 $\ln K = 0.60 + 0.02 S_a$

5) Percent of site with silt and sand substrate, S

1980 $\ln K = 0.53 + 0.01 S$

6) Percent of site with cobble substrate, S_c

1981 $K = 1.67 + 0.02 S_c$

7) Percent of site with cobble and boulder substrate, S_{cb}

1981 $\ln K = 0.47 + 0.01 S_{cb}$

8) Percent of site with gravel and cobble substrate, S_x

1981 $K = 0.26 - 0.007 S_x$

Fall Negative Correlations:

1) Percent of site with a depth of 0.26 to 0.75 m, D_t

$K = 4.03 - 0.06 D_t$

2) Percent of site with a current velocity of 11 to 20 cm/s, V_{11}

$K = 4.96 - 0.20 V_{11}$

Fall Positive Correlations:

3) Percent of site with a sand substrate, S_a

$$K = 1.58 + 0.17 \ln S_a$$

Winter Negative Correlations:

1) Gradient of site, G, in m/km

$$K = 1.70 - 0.14 \ln G$$

Winter Positive Correlations:

2) Percent of site with a depth, D_t, of 0.26 to 0.75 m

$$K = 1.25 - 0.01 D_t$$

3) Percent of site with a bedrock substrate, S_r

$$K = 1.54 + 0.01 S_r$$

4) Percent of site with boulder and bedrock substrate, S_e

$$\ln K = 0.39 + 0.005 S_e$$

Spring No Correlations

VITA

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